Survey and Inventory of Habitat and Fish Populations in Red Creek, Dolly Sods Wilderness Area, Monongahela National Forest

Center for Aquatic Technology Transfer
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Introduction

The USDA Forest Service is assigned by the Clean Water Act to protect air-quality related values of wilderness areas. In conjunction with this responsibility, the Monongahela National Forest (MNF) developed an action plan which involves inventorying and monitoring the effects of air pollution on air quality related values in Dolly Sods Wilderness Area. One of the MNF Action Plan objectives was to conduct basinwide surveys (a technique for inventorying total stream habitat and estimating fish distribution and abundance; Hankin and Reeves 1988) in the Dolly Sods Wilderness Area to establish a baseline for monitoring the effects of air pollution on aquatic communities.

We conducted a comprehensive basinwide survey of the Red Creek Watershed in July and August, 1997. With the exception of the extreme headwaters of the mainstem, Red Creek and its tributaries are within the Dolly Sods Wilderness Area (Figure 1). This watershed includes: Red Creek, Stonecoal Run, Little Stonecoal Run, Fisher Spring Run, Left Fork Red Creek, and an unnamed tributary (Figure 1). We used the basinwide visual estimation technique (BVET) (Hankin and Reeves 1988; Dolloff et al. 1993) to inventory stream habitat and fish in about 18 kilometers of stream within the watershed. The use of BVET allowed us to estimate total habitat area, percentage of pool and riffle area, and to classify and tally the stream substratum particle size distribution. We also mapped the distribution of woody debris, and measured the extent of disturbance by floods. In addition, the BVET was used to estimate the distributions and relative abundance of fish species occurring in the watershed.

Methods

Habitat

Sampling strata were based on naturally occurring habitat units including pools (an area in the stream with low water velocity, streambed gradient near zero, and a smooth water surface), and riffles (an area in the stream with relatively steep gradient, shallow water, relatively high velocity, and turbulent surface).

We used a two-stage visual estimation technique to quantify habitat in the study streams. During the first stage, all habitat units were classified and the surface area and maximum and average depth were estimated. Habitat was classified and inventoried by a two-person crew. One crew member identified each habitat unit by type, estimated wetted stream width, estimated stream channel width in riffles (at bankfull as described by Harrelson et. al 1994), and classified the dominant and subdominant substrata particle size (modified Wentworth scale). The remaining crew member classified and inventoried large woody debris (LWD) associated with each habitat unit (within the stream channel), estimated the maximum and average depth of all habitat units, and measured the depth of the riffle-crest in the tail of each pool. Average depth of each habitat unit was estimated by taking depth measurements at various places across the channel profile with a graduated staff marked in 0.1-ft increments. Woody debris greater than 4-ft long and greater than 4-in diameter was divided into four classes: 1) less than 15-ft long, less than 14-in diameter, 2) less than 15-ft long, greater than 14-in diameter, 3) greater than 15-ft long, less than 14-in diameter, and 4) greater than 15-ft long, greater than 14-in diameter. The length (0.1 ft) of each habitat unit was measured with a hip chain.

The first unit of each habitat type selected for intensive sampling (accurate measurement of surface area - *second stage sampling*) was determined randomly. Additional units were selected systematically (about one unit out of 10 for each habitat type). The wetted stream width, stream channel width, and the width of flood-disturbance in the riparian was measured at each of the systematically selected habitat units using either a 15-m measuring tape or a laser ranger-finder at intervals ranging from about 1 to 5 m.

Fish

We used underwater observation to estimate the distribution and relative abundance of each fish species in each of habitat units selected for intensive sampling. When a sample unit was encountered, divers entered at the downstream end and proceeded slowly upstream to the head of the unit while searching for and counting all fish species. When a fish was sighted, it was directed out of the line of travel by the diver's hand to prevent double counting.

We selected about 10% of the total number of units snorkeled in the Red Creek tributaries (with the exception of Little Stonecoal Run where we limited sampling to underwater observations in systematically selected habitat units: 13 pools and 11 riffles) for multiple-pass removal census (Zippen 1958) using one backpack DC electroshocker and dip nets . Electrofishing was used to (1) verify species identifications and counts made by divers and (2) obtain accurate measurements of fish lengths and weights. Because of its large size, electrofishing was used only for species verification and fish measurements in the mainstem of Red Creek. All fish were identified, measured for fork length (FL; mm) and total length (TL; mm), and weighed (0.1 g) before being returned to their approximate location of capture. Fish measurements were used to calculate length frequencies and summaries of length and weight for all species.

We used the method of bounded counts (Reiger and Robson 1967) for estimating fish abundance in selected habitat units of the mainstem of Red Creek. The bounded count is a technique which accounts for direct count bias; fish abundance can be calculated by a series of diver passes through a habitat unit. Populations are calculated according to the formula: $\dot{N} = 2N_m - N_{m-1}$, where N_m is the largest and N_{m-1} the second largest count in a series of passes throughout the sample unit (Reiger and Robson 1967).

BVET calculations were computed using a Statistical Analysis Systems (SAS) program developed by Dr. Patricia Flebbe (100 Cheatham Hall, VA Tech, Blacksburg, VA 24060). Data were summarized using a Quattro Pro spreadsheet, SigmaStat graphics software, and SigmaPlot statistical software.

Results

Habitat

Lower Red Creek - We identified 101 pools and 81 riffles in the lower Red Creek study section (4.9 km). Visual estimates of habitat areas were paired with measured habitat area for 20 (20%) pools, and 16 (20%) riffles. The lower study section of Red Creek contained 50.1% pool habitat (20,138.8 $\pm$ 1,278.3 m^2) and 49.9% riffle habitat (20,035.9 $\pm$ 698.1m^2) (Figure 2).

We identified boulder as the most common (modal) dominant and subdominant substrata for pools in the lower Red Creek study section (Figures 3 and 4). In riffles, the most common (modal) dominant and subdominant substrata were boulder and cobble respectively (Figures 3 and 4).

Maximum depth in the lower Red Creek study section ranged from a mean of 45.1 cm in riffles to 81.2 cm in pools (Figure 5). Average depth ranged from a mean of 28.6 cm in riffles to 52.2 cm in pools (Figure 6). The mean depth at riffle crest was 31.4 cm (Figure 7).

Lower Red Creek contained about 160 pieces of LWD per kilometer (Figures 8 and 9). This section, however, contained 33 pieces per kilometer of the larger, more stable size classes which are the most capable of forming instream habitat and providing cover for fishes (Figure 8).

The right-bank (facing upstream) flood disturbance width in the lower Red Creek study section ranged from 3.0 to 47.0 m ($\bar{x}$ = 19.1 m , n =13 ; Figure 10), and left-bank flood disturbance width ranged from 4.9 to 54.2 m ($\bar{x}$ = 17.8 m , n = 13; Figure 10).

Upper Red Creek - We identified 95 pools and 74 riffles in the upper Red Creek study section (4.4 km). Visual estimates of habitat areas were paired with measured habitat area for 19 (20%) pools, and 15 (20%) riffles. We estimated that the upper study section of Red Creek contained 44.3% pool habitat (13,327.3 $\pm$ 2,000.5 m^2) and 55.7% riffle habitat (16,986 $\pm$ 1,079.3 m^2) (Figure 11).

We identified boulder and large gravel as the most common (modal) dominant and subdominant substrata, respectively, in pools in the upper Red Creek study section (Figures 12 and 13). In riffles, the most common (modal) dominant and subdominant substrata were bedrock and boulder respectively (Figures 12 and 13).

Maximum depth in the upper Red Creek study section ranged from a mean of

38.7 cm in riffles to 82.3 cm in pools (Figure 14). Average depth ranged from a mean of 20.8 cm in riffles to 49.6 cm in pools (Figure 15). The mean depth at riffle crest was 27.9 cm (Figure 7).

Upper Red Creek contained about 259 pieces of LWD per kilometer (Figures 16 and 17). This section, however, contained 41 pieces per kilometer of the larger size classes (Figure 16).

The mean width of the flood disturbance (right and left banks combined) was 26.8 m (Figure 18). Disturbance from floods was less apparent in upper Red Creek than in the lower portion of the stream.

Red Creek (right fork) - We identified 26 pools and 16 riffles in the right fork of Red Creek study section(0.9 km). Visual estimates of habitat areas were paired with measured habitat area for 5 (19%) pools, and 3 (19%) riffles. We estimated that the right fork of Red Creek section contained 56.8% pool habitat (4,147.4 $\pm$ 533.9 m^2) and 43.2% riffle habitat (3,151.4 $\pm$ 22.9 m^2)(Figure 19).

Cobble and large gravel were the most common (modal) dominant and subdominant substrata, respectively, in pools of the right fork of Red Creek study section (Figures 20 and 21). In riffles, the most common (modal) dominant and subdominant substrata were bedrock and large gravel respectively (Figures 20 and 21).

Maximum depth in the right fork of Red Creek study section ranged from a mean of 33.1 cm in riffles to 62.4 cm in pools (Figure 22). Average depth ranged from a mean of 20.3 cm in riffles to 42.2 cm in pools (Figure 23). The mean depth at riffle crest was 17.2 cm (Figure 7).

Right fork of Red Creek contained about 30 pieces of LWD per kilometer (Figures 24 and 25). This section, however, contained only one piece per kilometer of the larger size classes (Figure 24).

Red Creek (left fork) - We identified 35 pools and 27 riffles in the left fork of Red Creek study section (0.8 km). Visual estimates of habitat areas were paired with measured habitat area for 7 (20%) pools, and 6 (22%) riffles. We estimated that the left fork of

Red Creek section contained 39.1% pool habitat (1,654.9 $\pm$ 83.1 m^2) and 60.9% riffle habitat (2,573.5 $\pm$ 380 m^2)(Figure 26).

We identified bedrock and boulder as the most common (modal) dominant and subdominant substrata, respectively, in pools of the left fork of Red Creek study section (Figures 27 and 28). In riffles, the most common (modal) dominant and subdominant substrata were boulder and cobble, respectively (Figures 27 and 28).

Maximum depth in the left fork of Red Creek study section ranged from a mean of 31.7 cm in riffles to 48.3 cm in pools (Figure 29). Average depth ranged from a mean of 19.1 cm in riffles to 32.7 cm in pools (Figure 30).

Left Fork of Red Creek contained about 137 pieces of LWD per kilometer (Figures 31 and 32). This section contained only seven pieces per kilometer of the larger size classes (Figure 31).

The right-bank (facing upstream) flood disturbance width in the left fork of Red Creek study section ranged from 2.0 to 6.1 m ($\bar{x}$ = 4.5 m , n =4 ; Figure 33), and left-bank flood disturbance width ranged from 4.0 to 28.0 m ($\bar{x}$ = 14.3 m , n = 4; Figure 33).

Stonecoal Run - We identified 201 pools and 116 riffles in the Stonecoal Run study section (5.6 km). Visual estimates of habitat areas were paired with measured habitat area for 34 (17%) pools, and 23 (20%) riffles. We estimated that the study section of Stonecoal Run contained 84.1% pool habitat (57,478.5 $\pm$ 690.1 m^2) and 15.9% riffle habitat (10,866.4 $\pm$ 466.7 m^2)(Figure 34).

We identified boulder and large gravel as the most common (modal) dominant and subdominant substrata, respectively, for pools in the Stonecoal Run study section (Figures 35 and 36). In riffles, the most common (modal) dominant and subdominant substrata were boulder and sand respectively (Figure 35 and 36). The dominant and subdominant substrata, however, varied between habitat types.

Maximum depth in the Stonecoal Run study section ranged from a mean of 32.4 cm in riffles to 59.5 cm in pools (Figure 37). Average depth ranged from a mean of 19.0 cm in riffles to 38.5 cm in pools (Figure 38). The mean depth at riffle crest was 7.9 cm (Figure 7).

Stonecoal Run contained about 93 pieces of LWD per kilometer (Figures 39 and 40). This section contained only six pieces per kilometer of the larger size classes (Figure 39).

The right-bank (facing upstream) flood disturbance width in the Stonecoal Run study section ranged from 1.4 to 18.4 m ($\bar{x}$ = 7.1 m , n =15 ; Figure 41), and left-bank flood disturbance width ranged from 0.7 to 9.6 m ($\bar{x}$ = 5.0 m , n = 15; Figure 41).

Fisher Spring Run - We identified 53 pools and 43 riffles in the Fisher Spring Run study section (1.1 km). Visual estimates of habitat areas were paired with measured habitat area for 10 (19%) pools, and 9 (21%) riffles. We estimated that the Fisher Spring Run section contained 24.3% pool habitat (950.7 $\pm$ 59.4 m^2) and 75.7% riffle habitat (2,961.7 $\pm$ 107.9 m^2)(Figure 42).

We identified boulder and cobble as the most common (modal) dominant and subdominant substrata, respectively, for pools in the Fisher Spring Run study section (Figures 43 and 44). In riffles, the most common (modal) dominant and subdominant substrata were boulder and cobble respectively (Figures 43 and 44).

Maximum depth in the Fisher Spring Run study section ranged from a mean of 30.8 cm in riffles to 51.8 cm in pools (Figure 45). Likewise, average depth ranged from a mean of 16.4 cm in riffles to 30.8 cm in pools (Figure 46). The mean depth at riffle crest was 14.6 cm (Figure 7).

Fisher Spring Run contained about 57 pieces of LWD per kilometer (Figures 47 and 48). This section, however, contained only three pieces per kilometer of the larger size classes (Figure 47).

Unnamed Tributary - We identified 45 pools and 33 riffles in the unnamed tributary study section (0.6 km). Visual estimates of habitat areas were paired with measured habitat area for 17 (38%) pools, and 10 (30%) riffles. We estimated that the unnamed tributary section contained 64.9% pool habitat (961.6 $\pm$ 64.9 m^2) and 35.1% riffle habitat (520.8 $\pm$ 38.3 m^2)(Figure 49).

We identified cobble and sand as the most common (modal) dominant and subdominant substrata, respectively, for pools in the unnamed tributary study section (Figures 50 and 51). In riffles, the most common (modal) dominant and subdominant substrata were boulder and cobble respectively (Figures 50 and 51).

Maximum depth in the unnamed tributary study section ranged from a mean of 20.3 cm in riffles to 32.4 cm in pools (Figure 52). Average depth ranged from a mean of 12.2 cm in riffles to 23.3 cm in pools (Figure 53). The mean depth at riffle crest was 6.9 cm (Figure 7).

The unnamed tributary contained about 117 pieces of LWD per kilometer (Figures 54 and 55). This section contained only seven pieces per kilometer of the larger size classes which are the most stable and most capable of forming instream habitat and providing cover for fishes (Figure 54).

Fish Distribution and Abundance

We observed and/or captured 10 species of fish in the Red Creek study area (Table 1). With the exception of creek chubs (*Semotilus atromaculatus*), which were observed throughout the mainstem of Red Creek, all species were observed only within the lower four km of the stream. No fish were observed during intensive underwater observation or captured with electrofishing in Little Stonecoal Run, Stonecoal Run, or Fisher Spring Run (Figures 56, 57, and 58).

Creek chubs (adults and YOY) and YOY white suckers (*Catostomus commersoni*) were the only two species found in enough paired samples (units selected for bounded counts) to be a useful verification of diver counts. Nevertheless, the relationships between diver counts and bounded count estimates for these species (and size classes) were significant, highly correlated, and the data close to a line through the origin; suggesting the diver counts were precise (Figure 59).

Creek chubs were the most abundant and widely distributed species observed in the study area (Figure 60). Although we observed the species throughout the mainstem of Red Creek, the species appeared to be the most common upstream of the Stonecoal Run confluence (Figure 60). We counted an average of 3.4 adults per 100 rm (river meter; n = 77; range = 0 - 61) and 86 YOY (young-of year) per rm (n = 77;

range = 0 - 901) in the habitat units sampled by divers.

Longnose dace (*Rhinichthys cataractae*) were relatively abundant and well distributed in lower Red Creek (Figure 61). We observed considerably more adult longnose dace (n = 77; $\bar{x}$ = 3.4/100 rm; range = 0 -61) than YOY (n = 77; $\bar{x}$ = 0.04/100 rm; range = 0 - 3.4).

White suckers were also well distributed and relatively abundant in lower Red Creek (Figure 62); however, YOY comprised the greatest proportion of the population observed by divers. We observed an average of 21.2 YOY white suckers per 100 rm (n = 77; range = 0 - 705) but less than 0.67 adults per 100 rm (n = 77; range = 0 - 35).

Brook trout (*Salvelinus fontinalis*) and rainbow trout (*Oncorhynchus mykiss*) were the only game fish observed in the study area. Overall, brook trout was the most abundant and widely distributed of the two species (Figures 63 and 64). Adult brook trout densities range from 0.0 to 11.8 per 100 rm (n = 77; $\bar{x}$ = 0.5) and adult rainbow trout densities ranged from 0.0 to 17.7 per 100 rm (n = 77; $\bar{x}$ = 0.3). We also observed and average of 0.6 YOY brook trout per 100 rm (n = 77; range = 0 - 7.9) but we did not observe or capture YOY rainbow trout. We also collected brook trout, using three-pass electrofishing, throughout the unnamed tributary (Figure 65). Three-pass depletion estimates (Zippen 1958) ranged from 0.0 to 19.5 (n = 17; $\bar{x}$ = 6.5) YOY per habitat unit (Figure 66; n = 17; $\bar{x}$ = X/100 rm); however, only one adult was captured.

We observed mottled sculpin (*Cottus bairdi*) in six habitat units in lower Red Creek (Figure 67). An average of 0.4 YOY per 100 rm (n = 77; range = 0 - 10.6) and zero adult mottled sculpin were observed.

Similarly, central stonerollers (*Campostoma anomalum*) were detected in four habitat units in lower Red Creek (Figure 68); however, only adult stonerollers were observed. We observed a maximum of 14 stonerollers per 100 rm although the mean density was less than 0.3 per 100 rm.

Blacknose dace (*Rhinichthys atratulus*), river chub (*Semotilus atromaculatus*), and northern hogsucker (*Hypentelium nigricans*) were detected only with electrofishing gear. All three species were collected in low numbers (n < 3 in all cases) and appear to have a limited distribution downstream of Little Stonecoal Run (Figures 69, 70, and

71).

Fish Length and Weight

The mean TL and weight of 42 creek chubs captured with electrofishing gear was 41.4 mm (range = 20 - 288) and 3.1 g (range = 0.1 - 26.0), respectively (Figures 72A, and 72B). Length frequency analysis show the Red Creek population to be skewed toward the YOY (Figure 72C). The high frequency of YOY, relative to adults, observed during the electrofishing survey was similar to that observed by divers and suggest that these results were not caused by biases associated with sampling techniques.

Twenty-six longnose dace captured had a mean TL of 65.3 mm (range = 26 - 110 mm; Figure 73A) and a mean weight of 3.4 g (range = 0.1 - 14.2; Figure 73B). Length frequency analysis indicate that the size classes of this species was normally distributed (Figure 73C).

White suckers averaged 41.9 mm TL (n = 26; range = 27 - 172; Figure 74A) and 2.2 g weight (n = 26; range = 46.1 - 0.2; Figure 74B). All but one of the white suckers captured were YOY (Figure 74C). We also observed a similar distribution during the underwater census.

Rainbow trout were not present in any of the electrofishing samples. Only four YOY and two adult brook trout (Figure 75C) were captured in Red Creek and ranged in size from 74 to 304 mm TL ($\bar{x}$ = 146.8; Figure 75A) and 4.0 to 317.7 g weight ($\bar{x}$ = 89.5; Figure 75B). Young-of- year brook trout were also the most common year class observed in the unnamed tributary: only one adult was captured (Figure 76C). The average TL of YOY brook trout in the unnamed tributary was 48 mm and ranged from 31 to 70 mm (Figure 76A). The average weight was 1.2 grams with a range of 0.2 to 2.9 grams (Figure 76B). Young-of-year brook trout in the unnamed tributary appear to be smaller than YOY brook trout captured in the mainstem of Red Creek (mean TL = 84 mm; mean weight = 6.5 g). This data, however, should be in interpretated with caution due to the small number of YOY brook trout captured in Red Creek (n = 4).

The numbers of mottled sculpin, blacknose dace, river chub, and central stoneroller collected was too low to make meaningful inferences about their populations. Therefore, summaries of their populations are given in Figures (77, 78, 79, and 80).

Discussion

In general, the Red Creek watershed is depauperate of fish. Creek chub was the only relatively abundant and widely distributed species in the mainstem of Red Creek. The remaining species had limited or patchy distributions and/or occurred in low numbers. Further, we observed fish in only one of the four Red Creek tributaries studied. Although no fish were observed in these tributaries, we did observe numerous crayfish (unidentified species) in both Little Stonecoal Run and Stonecoal Run and two spring salamanders (*Gyrinophilus porphyriticus*) in Little Stonecoal Run.

At present, we lack the information necessary for determining the factors influencing the observed distribution, abundance, and fish community in the Red Creek watershed. Although numerous factor can influence the distribution and abundance of fish, two factors are highly suspect in the watershed: past floods and water quality. Integration of data collected in this study with water quality data should provide insight into our observations in the Red Creek watershed.

We also observed considerable flood damage in the mainstem Red Creek and, to a lesser extent, its tributaries. Floods can displace fish, destroy habitat, or disrupt spawning. In general, fish can recolonize disturbed areas in a relatively short period of time, ranging from a few days to several years. The amount of time needed for recolonization depends on several factors including the type and extent of the disturbance, distance to source populations, and occurrence of barriers to movement (Cairns et al. 1971; Gore and Milner 1990; Detenbeck et al. 1992). It is important to note that we observed a series of waterfalls that are potential barriers to fish migration on Red Creek between Stonecoal Run and Fisher Spring Run (between 4 and 5 km upstream of the lower study boundary). Only creek chubs were observed above these falls.

This study provides information on stream habitat and fish distribution and abundance in the Red Creek watershed. This information, in conjunction with water quality data, can serve as a baseline for managers and researchers involved in monitoring the effects of air pollution on aquatic communities in the Dolly Sods Wilderness Area.

Literature Cited

Detenbeck, N. E., P.W. Devore, G. J. Niemi, and A. Lima. 1992. Recovery of temperate-stream fish communities from disturbance: a review of case studies and synthesis of theory. Environmental Management 16:33 -53.

Cairns, J., Jr., J. S. Crossman, K. L. Dickson, and E. E. Herricks. 1971. The recovery of damaged streams. ASB (Association of Southeastern Biologists) Bulletin 18:79 -106.

Gore, J. A., and A. M. Milner. 1990. Island biogeographical theory: can it be used to predict lotic recovery rates? Environmental Management 14: 737 - 753.

Dolloff, C. A., D. G. Hankin, and G. H. Reeves. 1993. Basinwide estimation of habitat and fish populations in streams. General Technical Report SE-83. Asheville, North Carolina: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experimental Station. 25 pp.

Hankin, D. G. and G. H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Sciences. 45: 834-844.

Harrelson, Cheryl C.; Rawlins, C. L.; Potyondy, John P. 1994. Stream channel reference sites: an illustrated guide to field technique. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61p.

Reiger, H. A., and D. S. Robson. 1967. Estimating population number and mortality rates. Pages 31 - 66 *in* S. D. Gerking, editor. The biological basis of freshwater fish production. Blackwell Scientific Publications, Oxford, UK.

Zippen, C. 1958. The removal method of population estimation. Journal of Wildlife Management 22: 82 - 90.

Table 1. Fish species observed in Red Creek.

Common Name	Scientific Name
brook trout	*Salvelinus fontinalis*
rainbow trout	*Onchorhyncus mykiss*
river chub	*Nocomis micropogon*
creek chub	*Semotilus atromaculatus*
central stoneroller	*Campostoma anomalum*
blacknose dace	*Rhinichthys atratulus*
longnose dace	*Rhinichthys cataractae*
mottled sculpin	*Cottus bairdi*
northern hogsucker	*Hypentelium nigricans*
white sucker	*Catostomus commersoni*

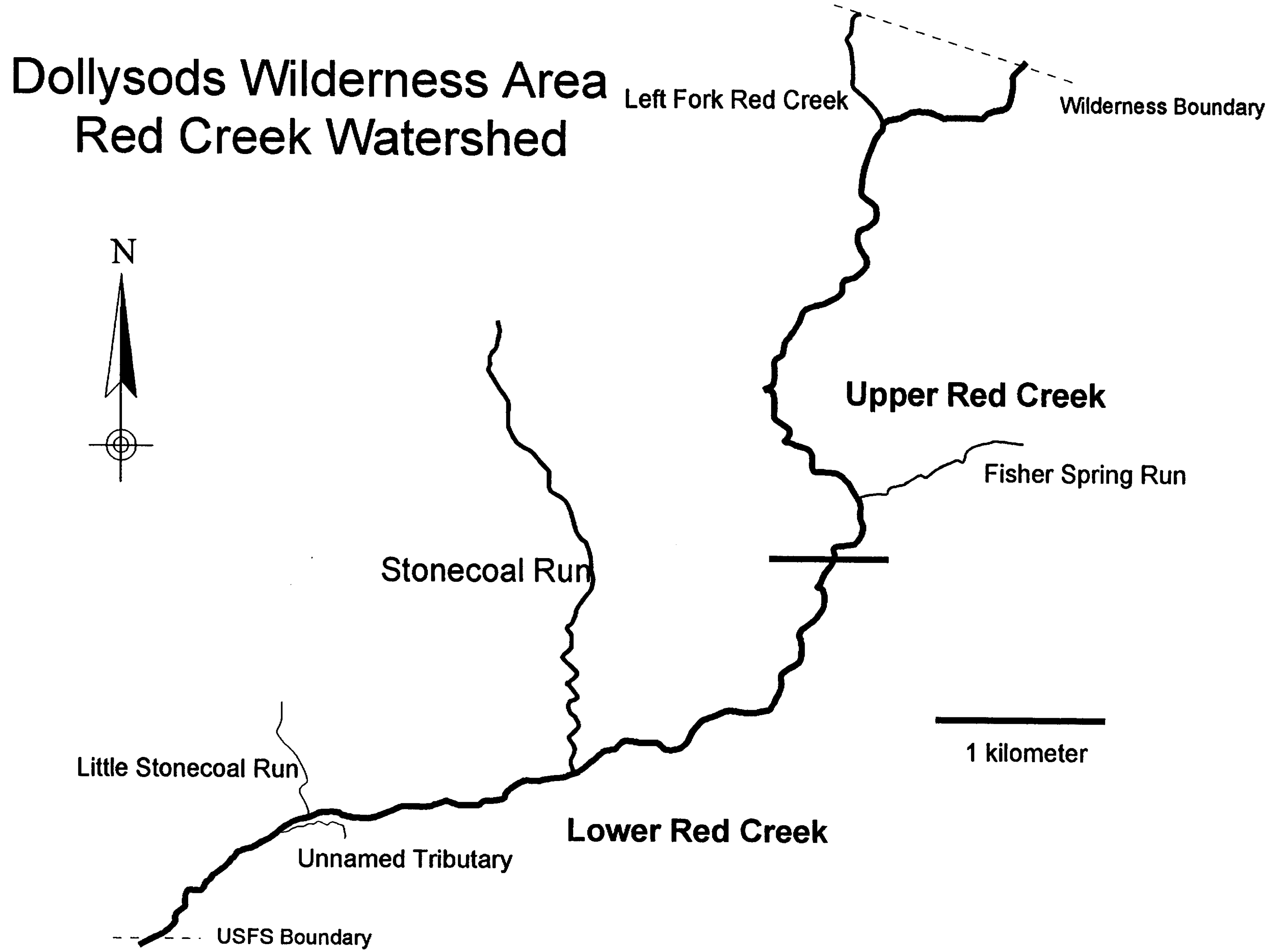

Figure 1. Map showing the Red Creek Wztershed in Dollysods Wilderness Area. The main branch of Red Creek was broken up into two sections. All other stream sections were surveyed to marginal habitat or boundaries.

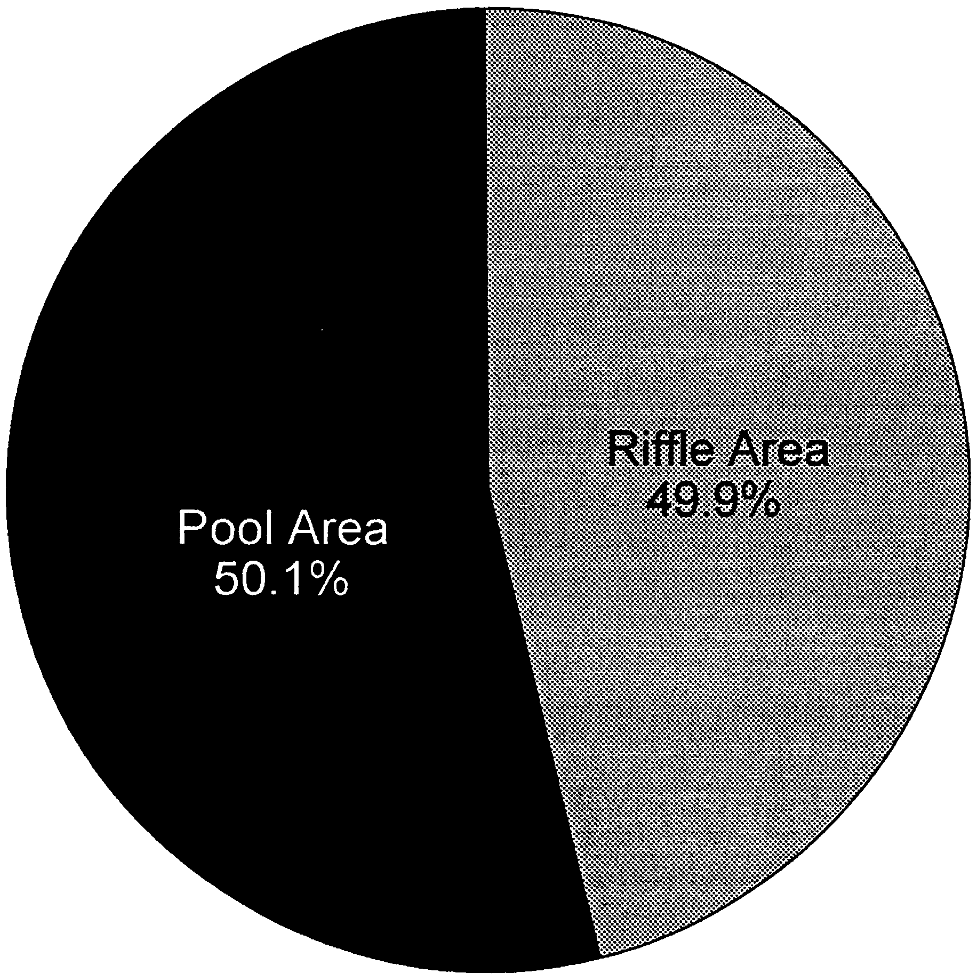

Figure 2. Percent pool and riffle area in the Lower Red Creek section.

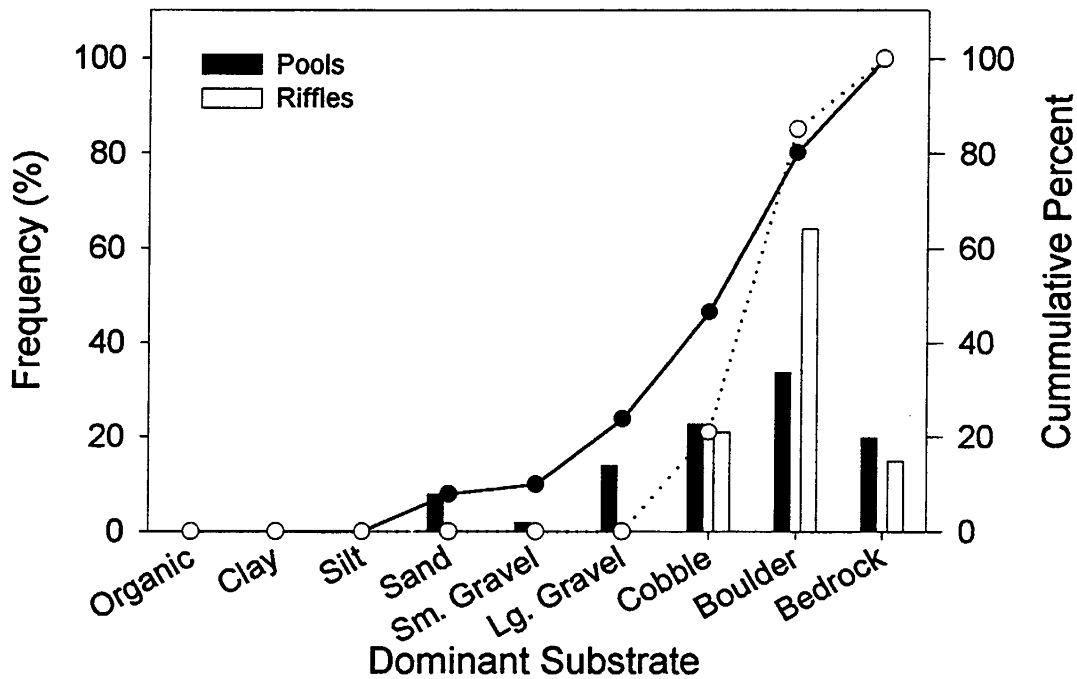

Figure 3. Frequency (percent) of dominant substrate occurrence by habitat type in Lower Red Creek . Solid dots represent cumulative percent of pools and open dots represent cumulative percent of riffles.

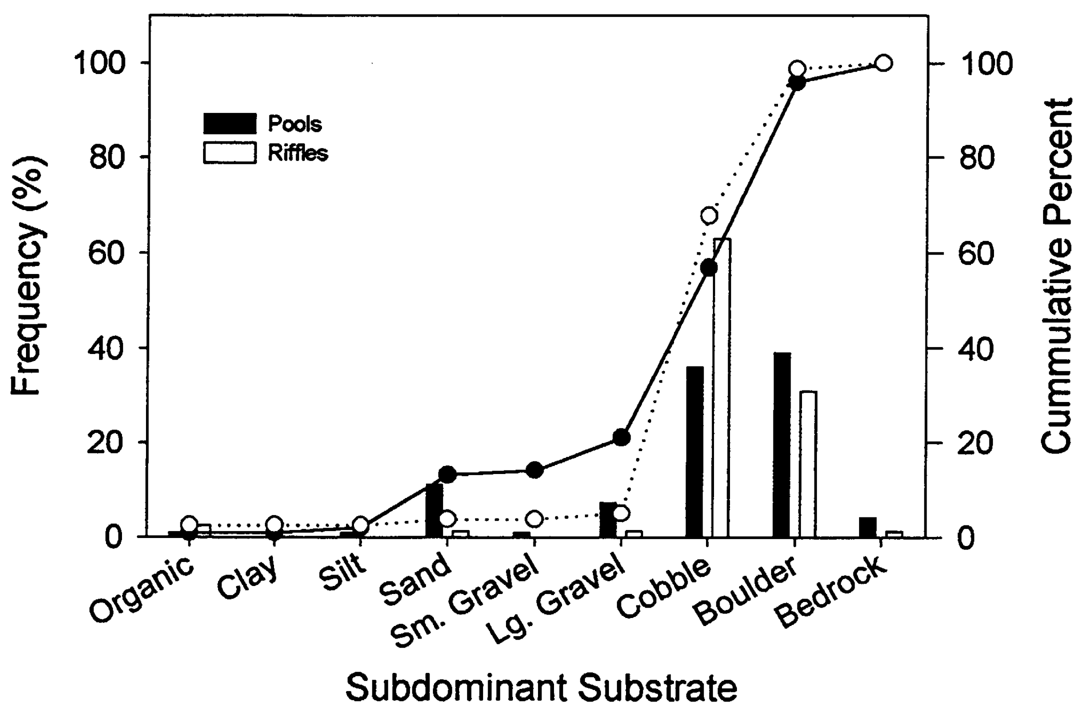

Figure 4. Frequency (percent) of subdominant substrate occurrence by habitat type in Lower Red Creek. Solid dots represent cumulative percent of pools and open dots represent cumulative percent of riffles.

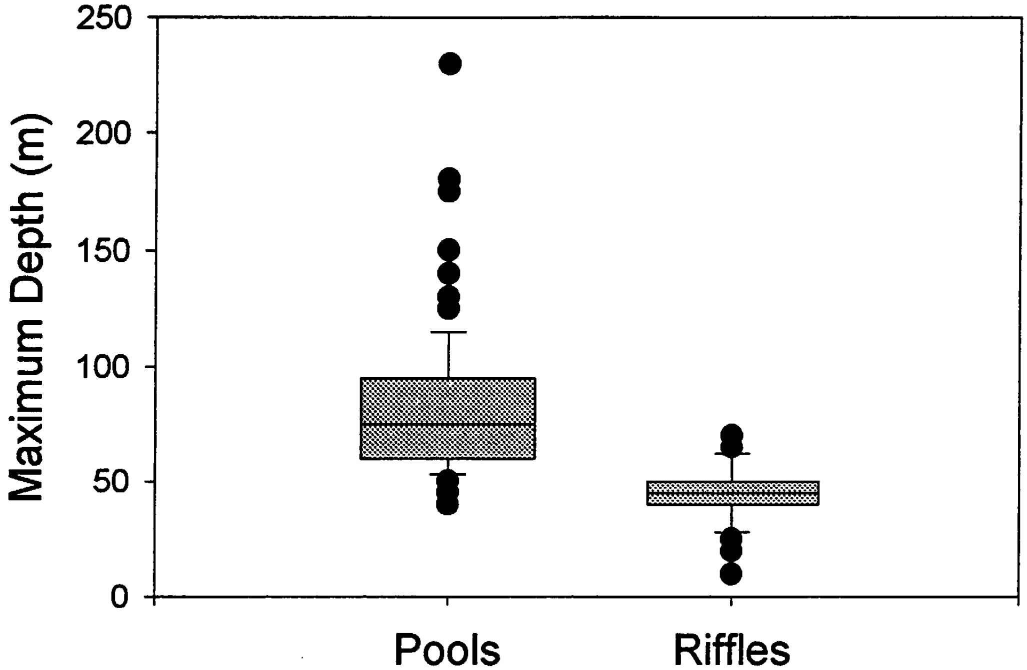

Figure 5. Box plots for habitat-unit maximum depth in Lower Red Creek.
The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

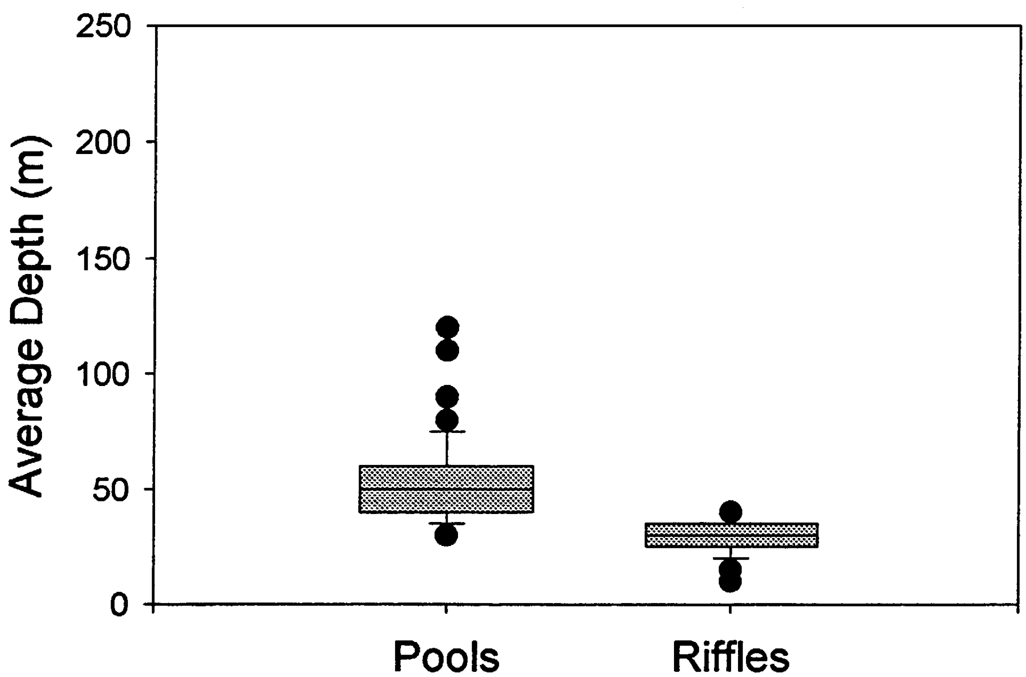

Figure 6. Box plots for habitat-unit average depth in Lower Red Creek.
The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

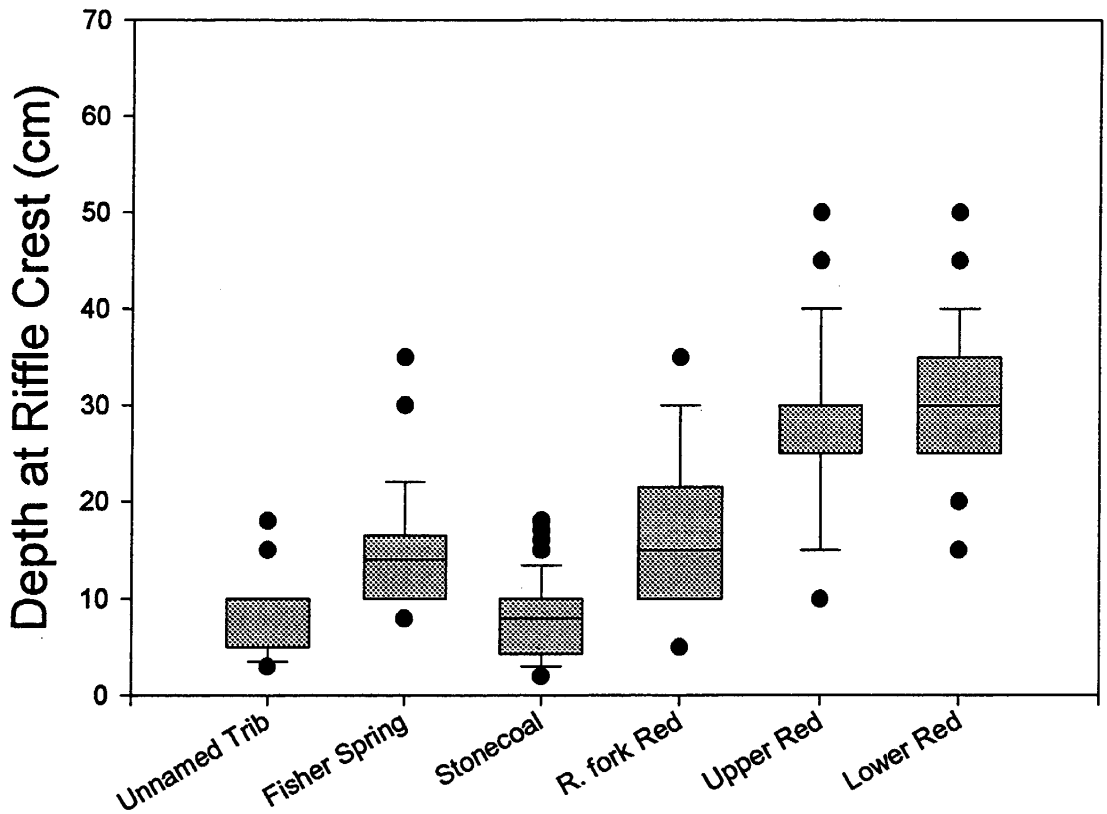

Figure 7. Box plots for riffle crest depth for streams in the Red Creek Watershed. The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

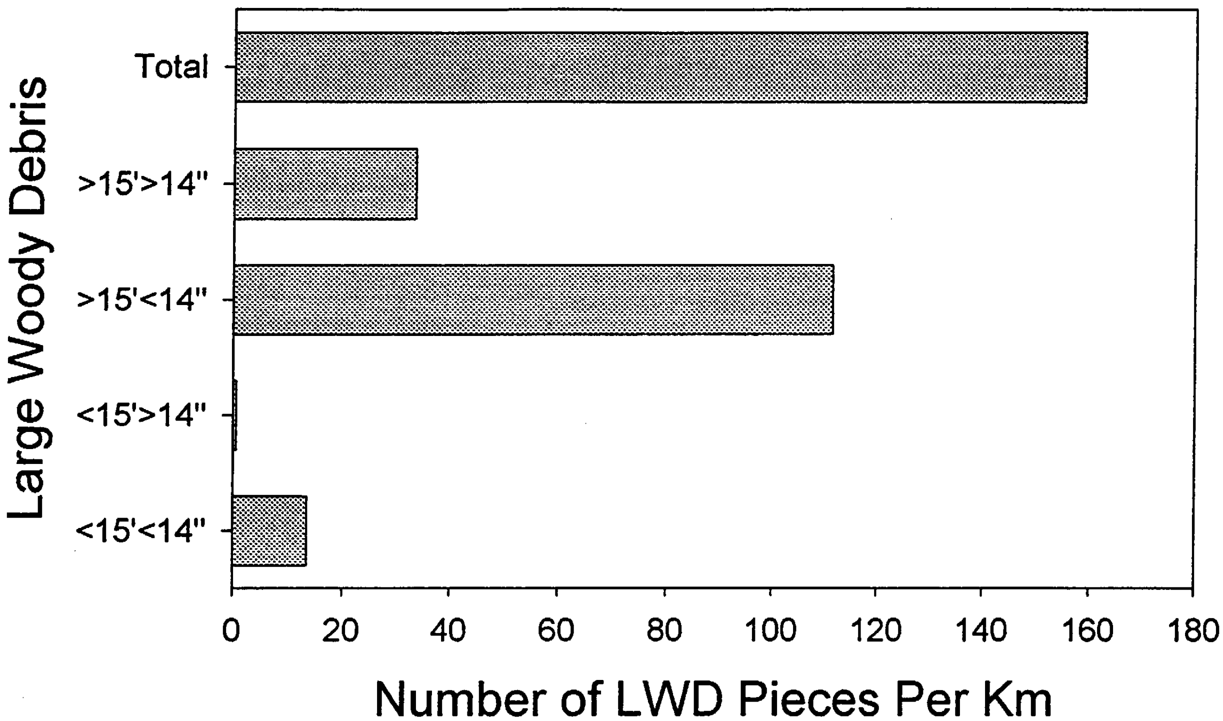

Figure 8. Pieces of large woody debris per kilometer in Lower Red Creek.

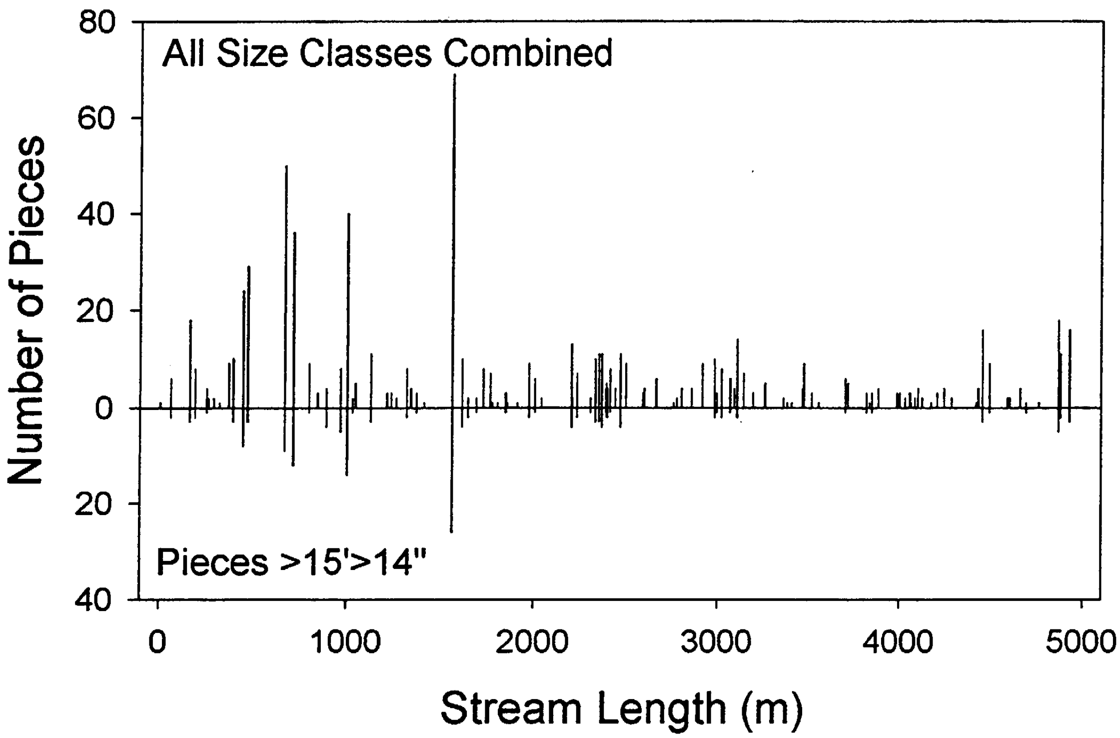

Figure 9. Distribution and total abundance of large woody debris in Lower Red Creek.

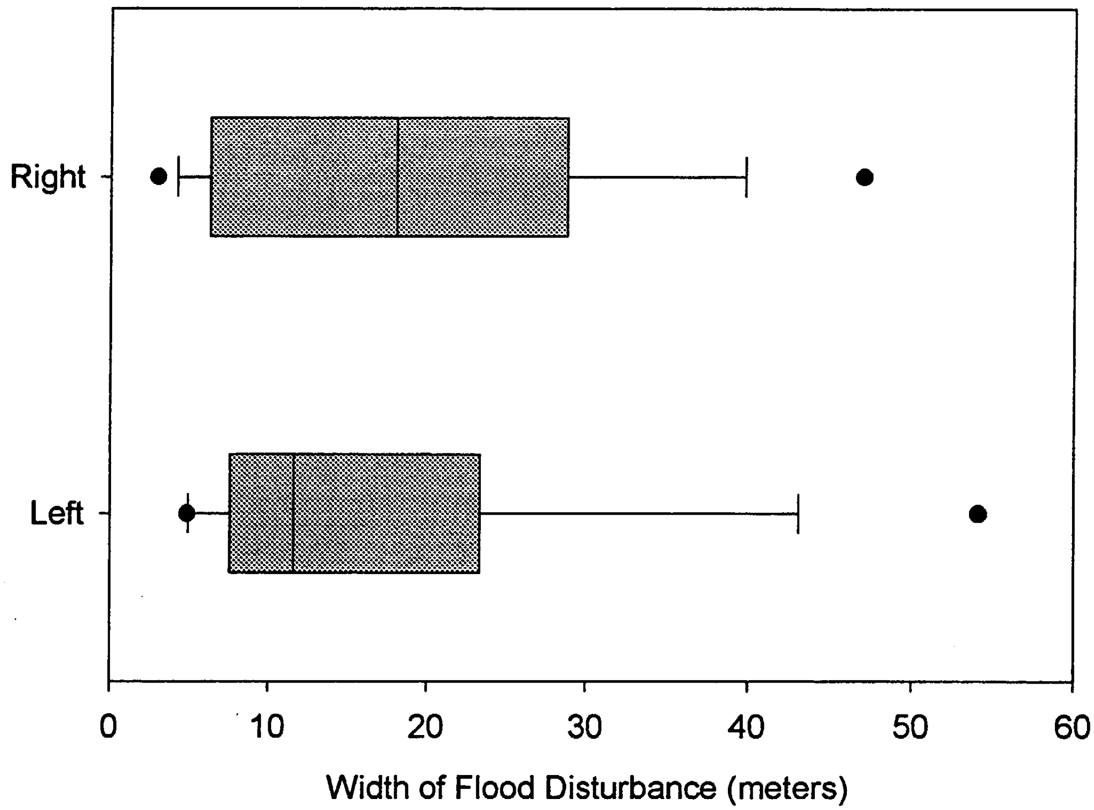

Figure 10. Box plots of visable flood disturbance from the water's edge (right and left sides) in Lower Red Creek. The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

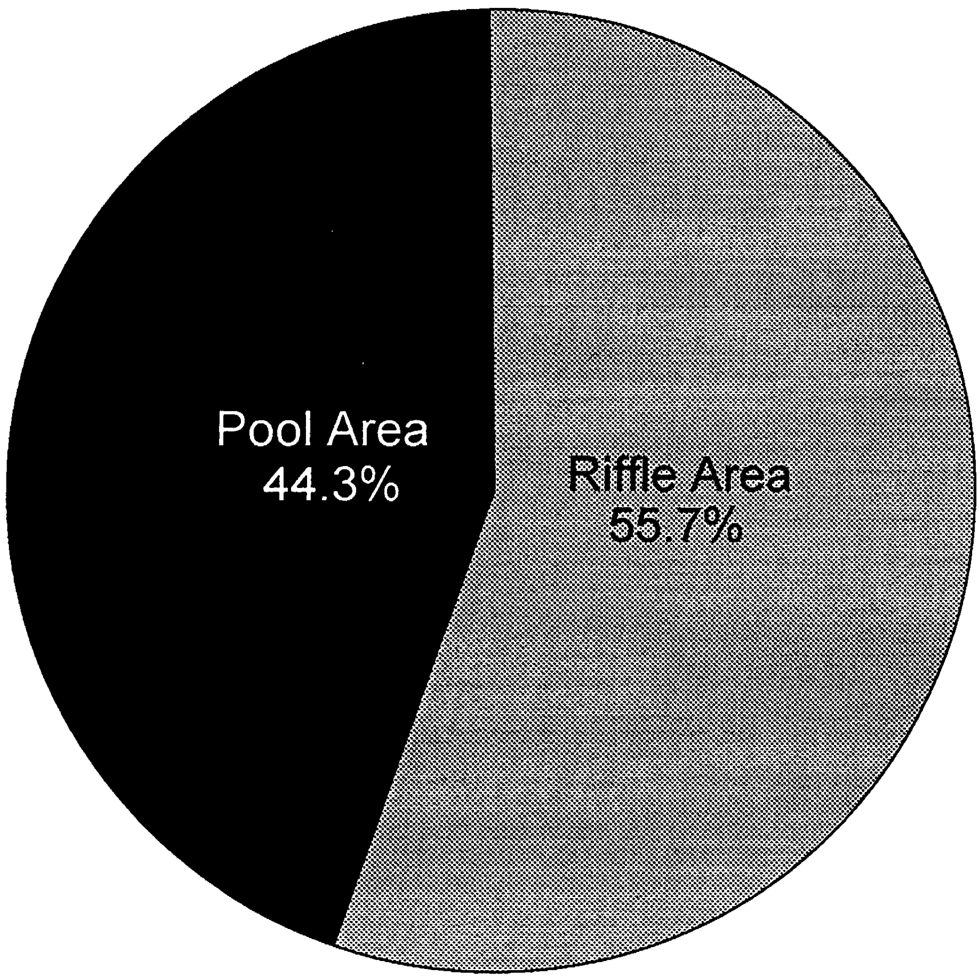

Figure 11. Percent pool and riffle area in the Upper Red Creek section.

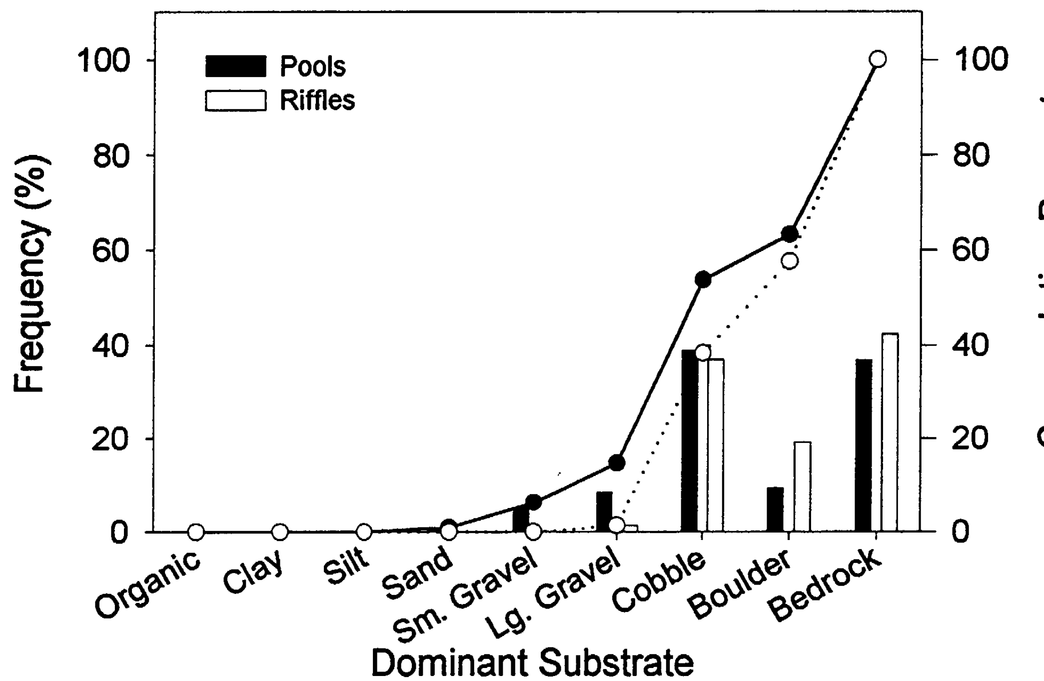

Figure 12. Frequency (percent) of dominant substrate occurrence by habitat type in Upper Red Creek . Solid dots represent cumulative percent of pools and open dots represent cumulative percent of riffles.

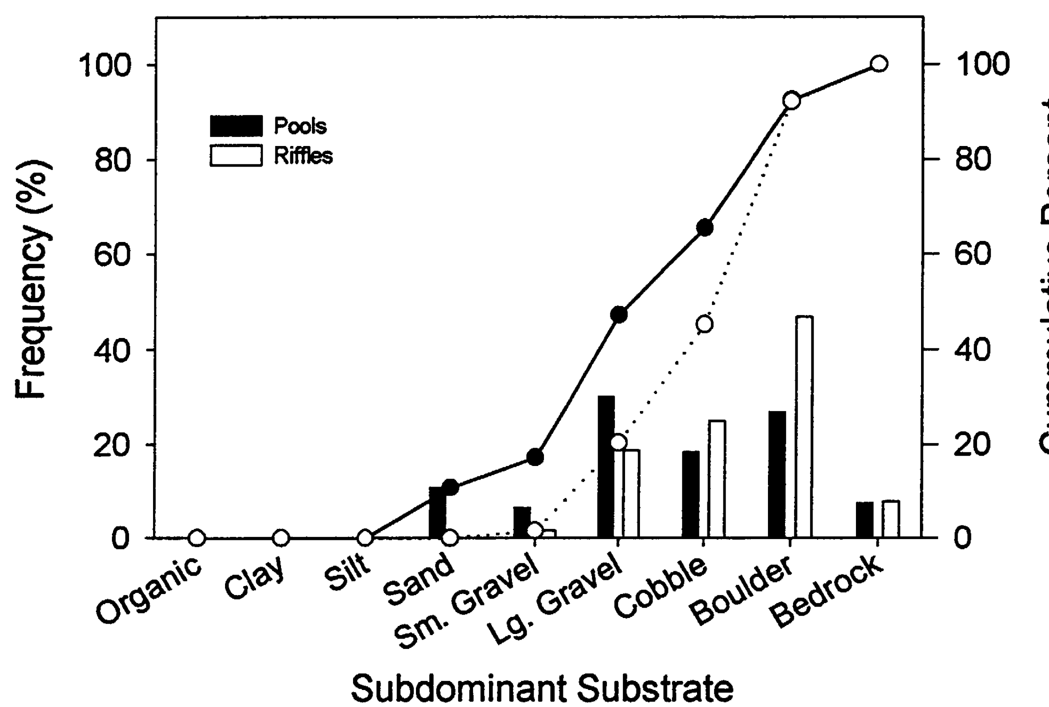

Figure 13. Frequency (percent) of subdominant substrate occurrence by habitat type in Upper Red Creek. Solid dots represent cumulative percent of pools and open dots represent cumulative percent of riffles.

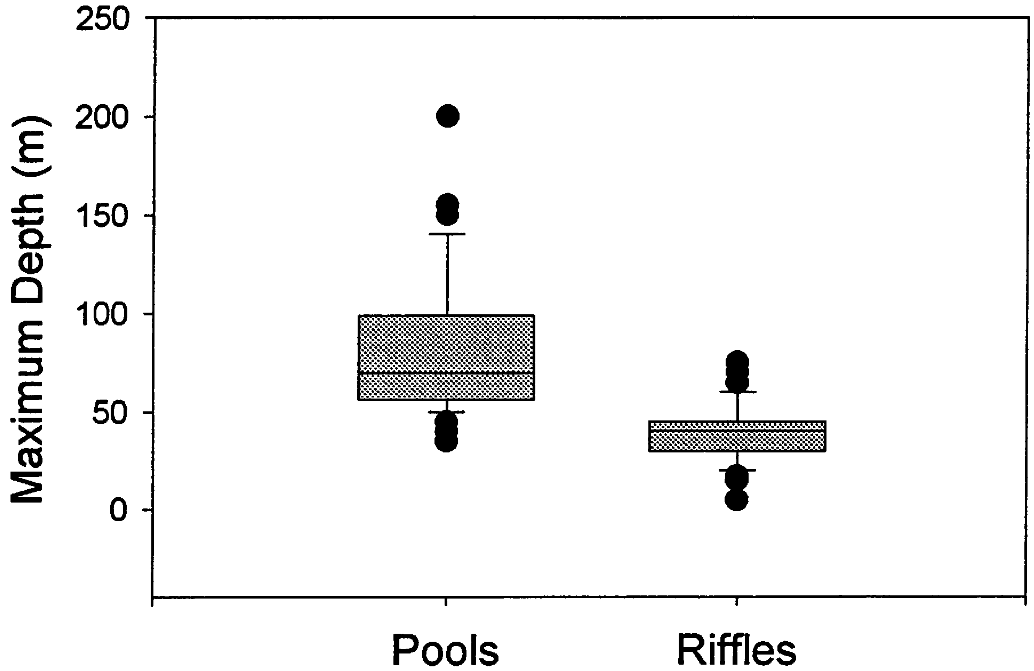

Figure 14. Box plots for habitat-unit maximum depth in Upper Red Creek.
The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

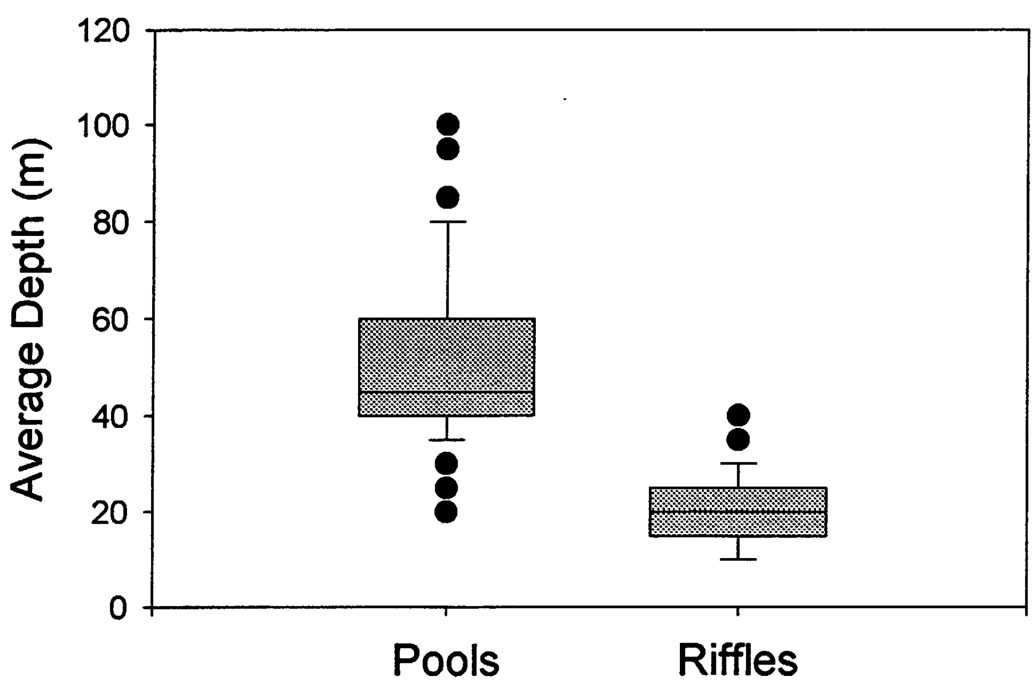

Figure 15. Box plots for habitat-unit average depth in Upper Red Creek.
The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

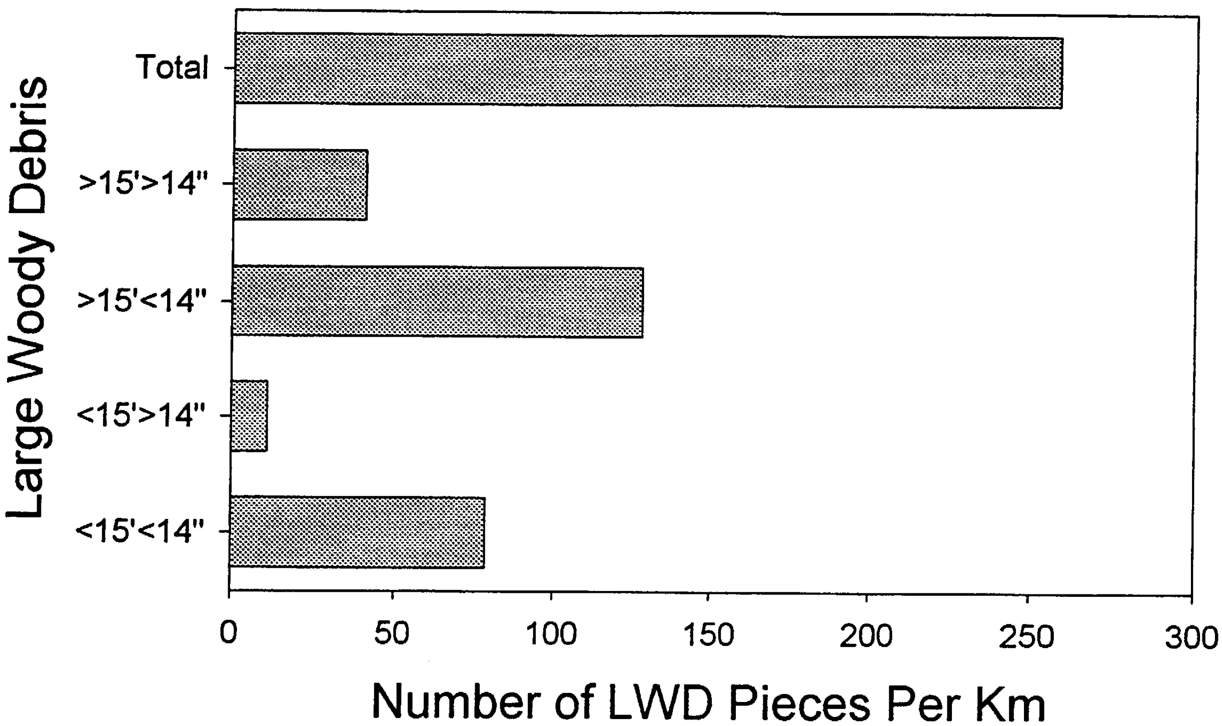

Figure 16. Pieces of large woody debris per kilometer in Upper Red Creek.

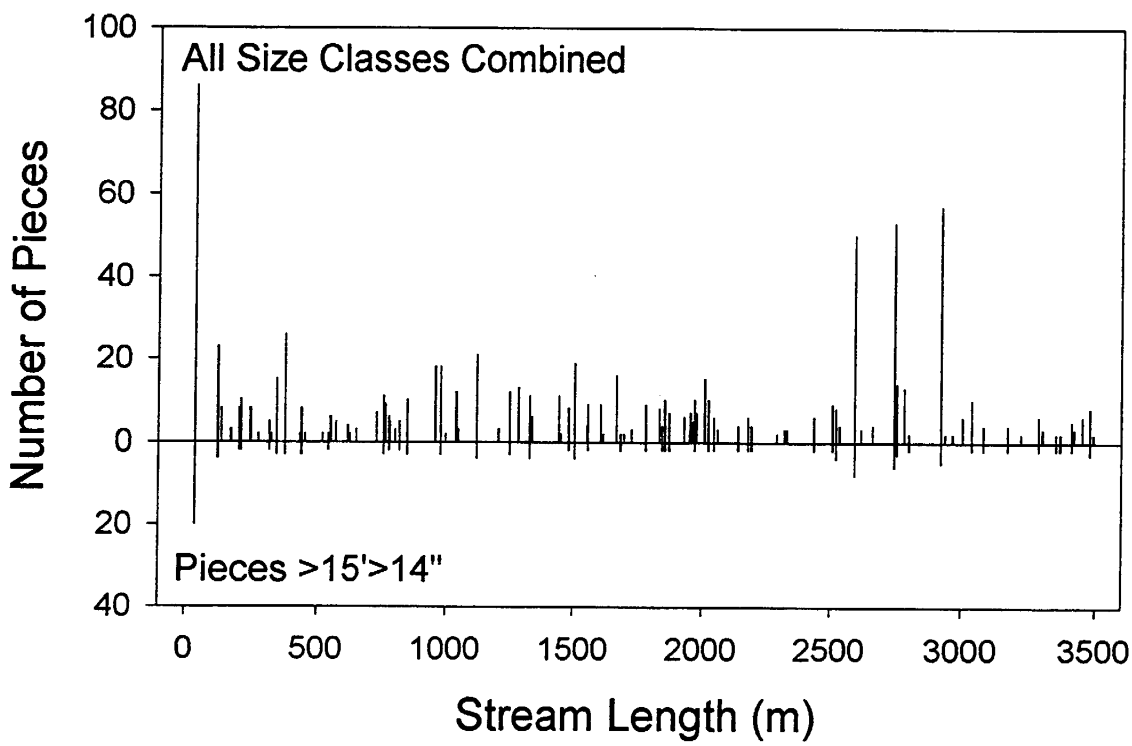

Figure 17. Distribution and total abundance of large woody debris in Upper Red Creek.

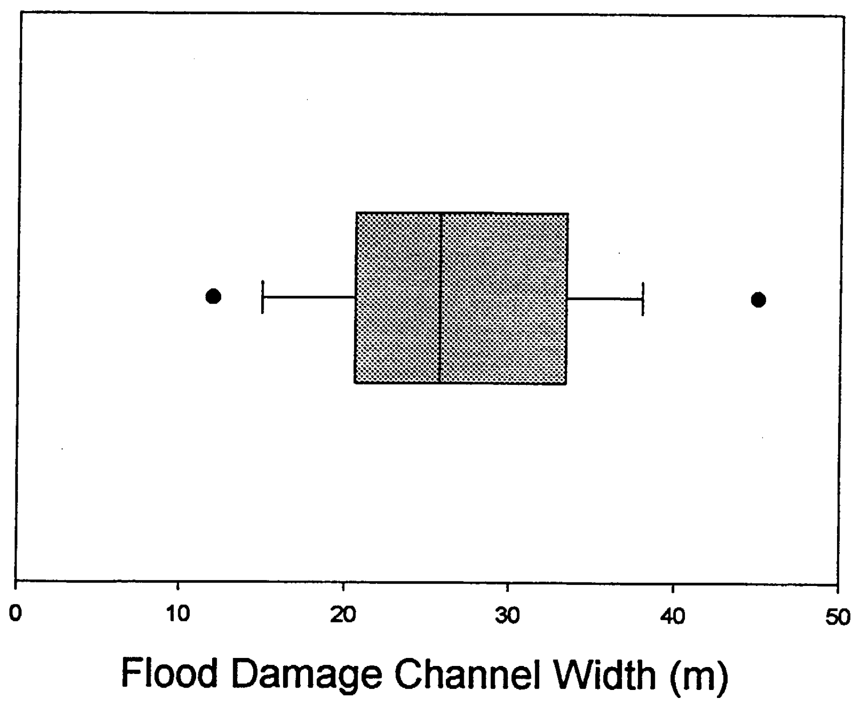

Figure 18. Box plot showing the flood damaged channel width in Upper Red Creek. The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

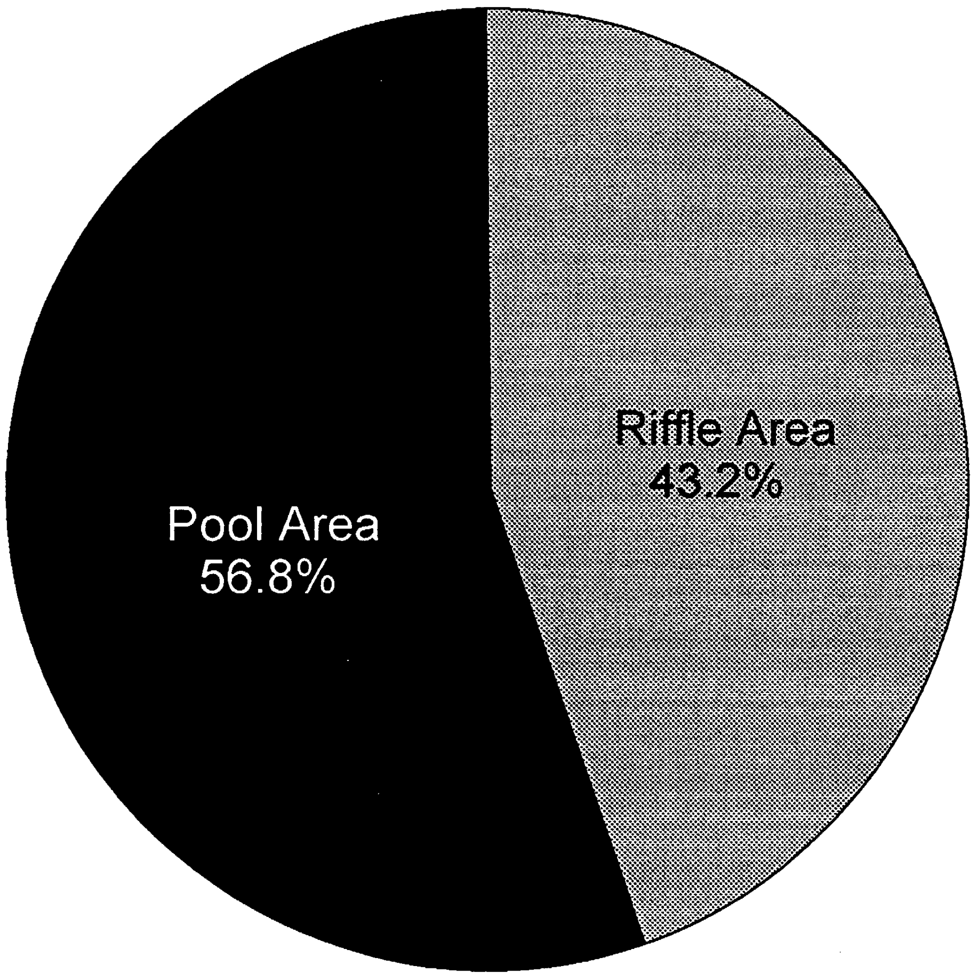

Figure 19. Percent Area of pools and riffle habitat types in the right fork of Red Creek.

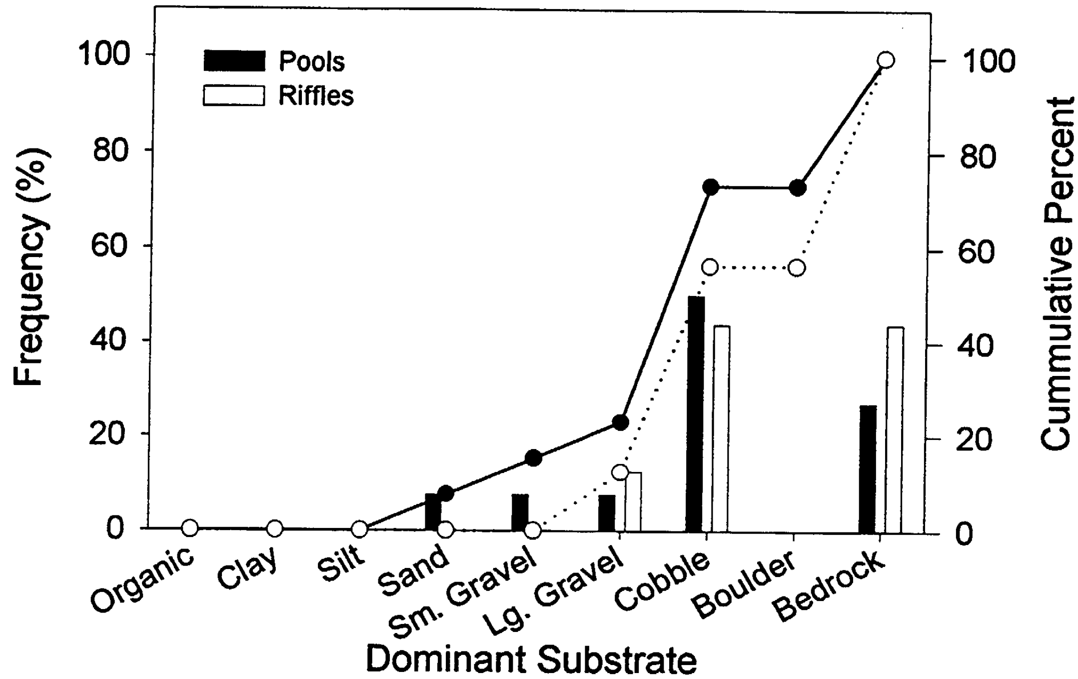

Figure 20. Frequency (percent) of dominant substrate occurrence by habitat type in the right fork of Red Creek. Solid dots represent cumulative percent of pools and open dots represent cumulative percent of riffles.

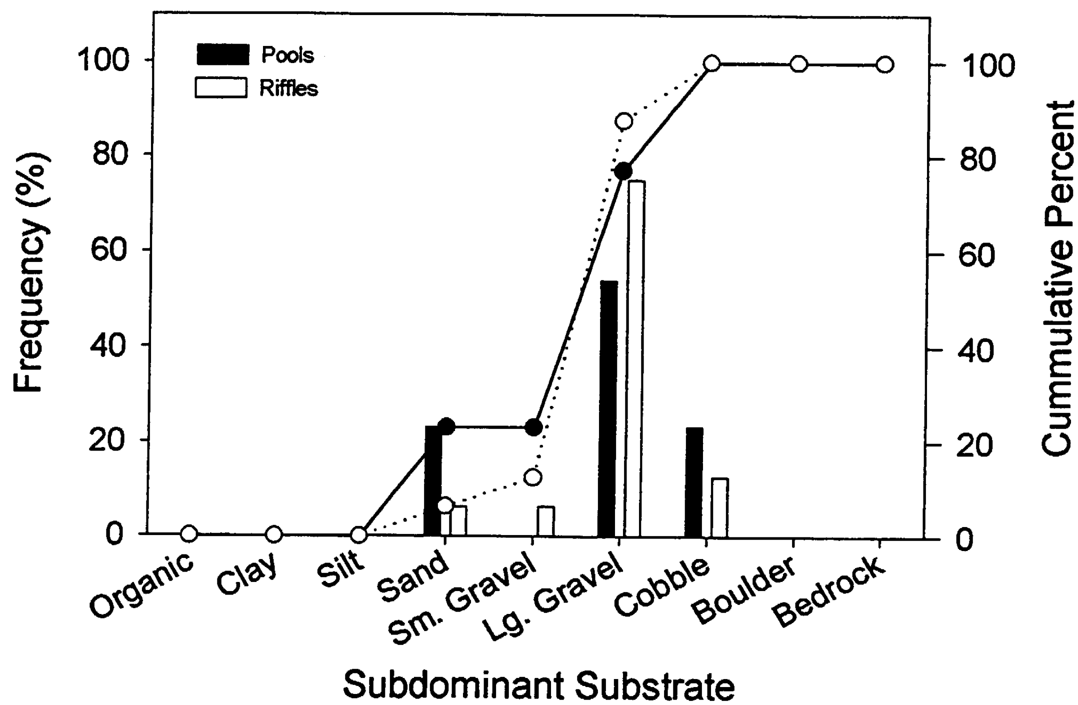

Figure 21. Frequency (percent) of subdominant substrate occurrence by habitat type in the right fork of Red Creek. Solid dots represent cumulative percent of pools and open dots represent cumulative percent of riffles.

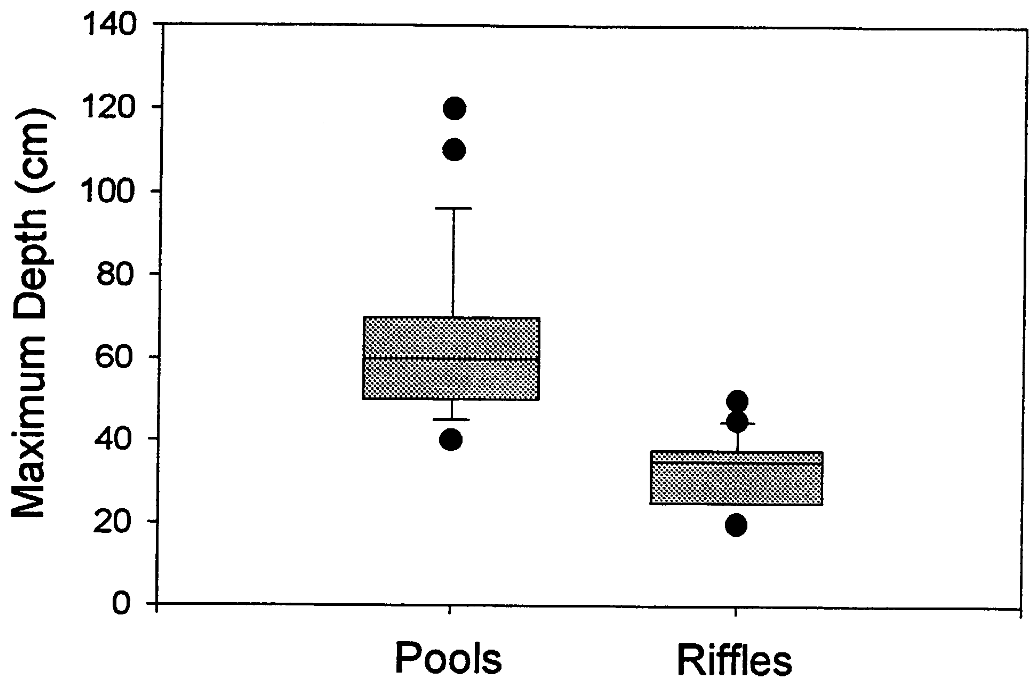

Figure 22. Box plots for habitat-unit maximum depth in the right fork of Red Creek. The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

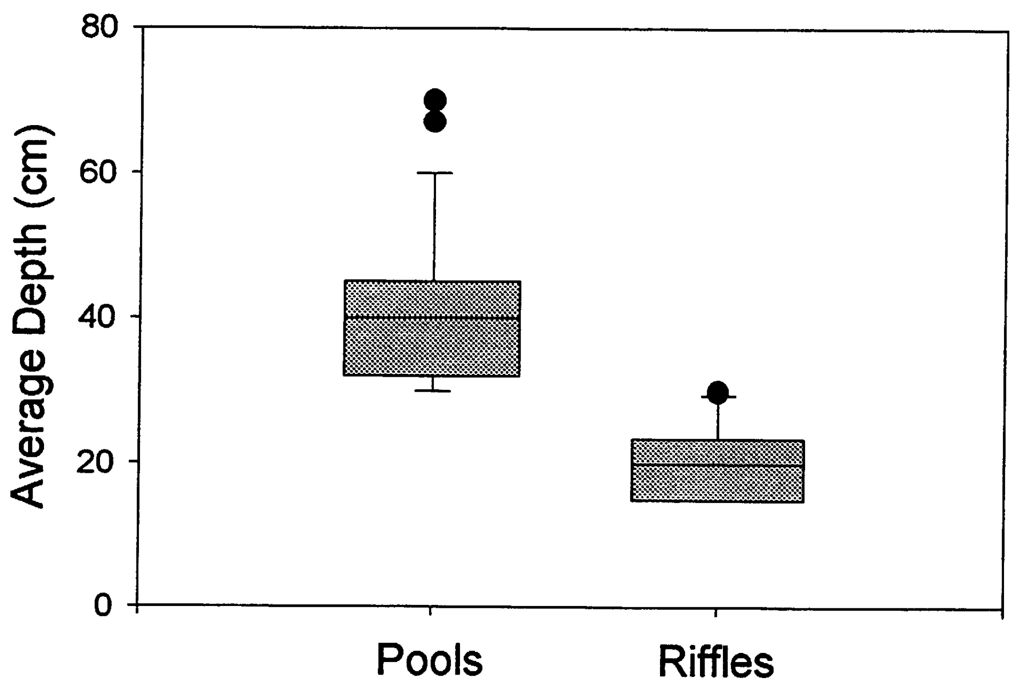

Figure 23. Box plots for habitat-unit average depth in the right fork of Red Creek. The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

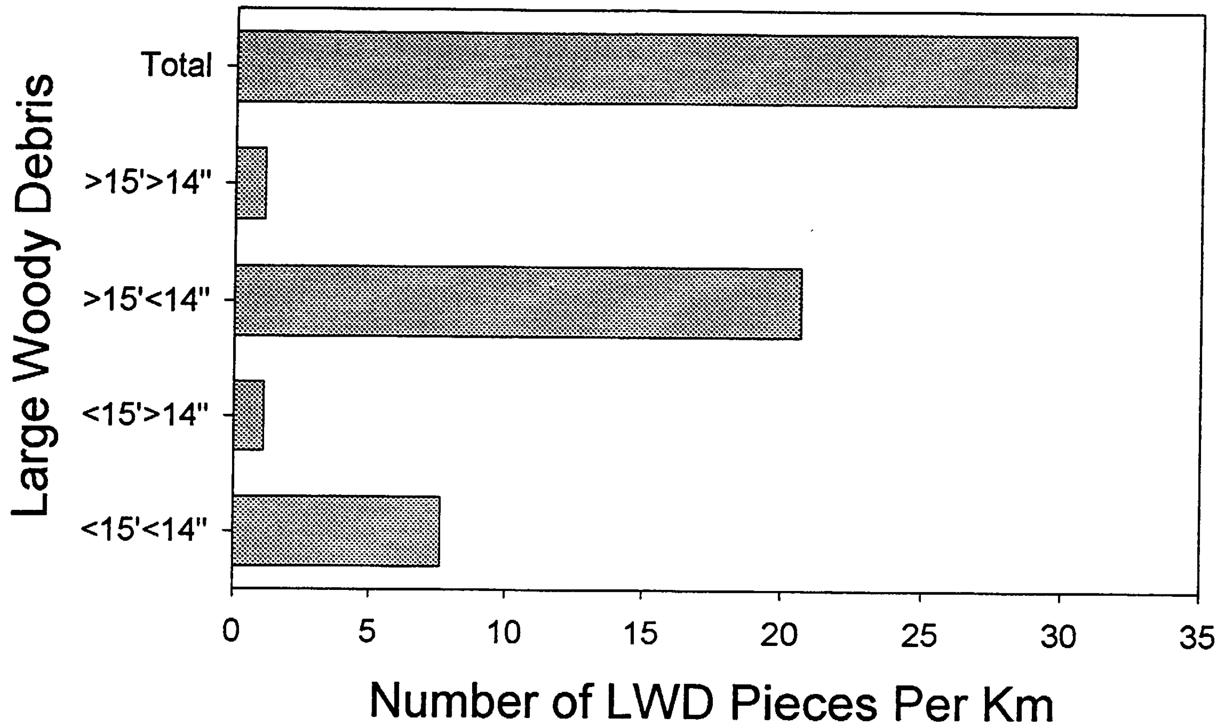

Figure 24. Pieces of large woody debris per kilometer in the right fork of Red Creek.

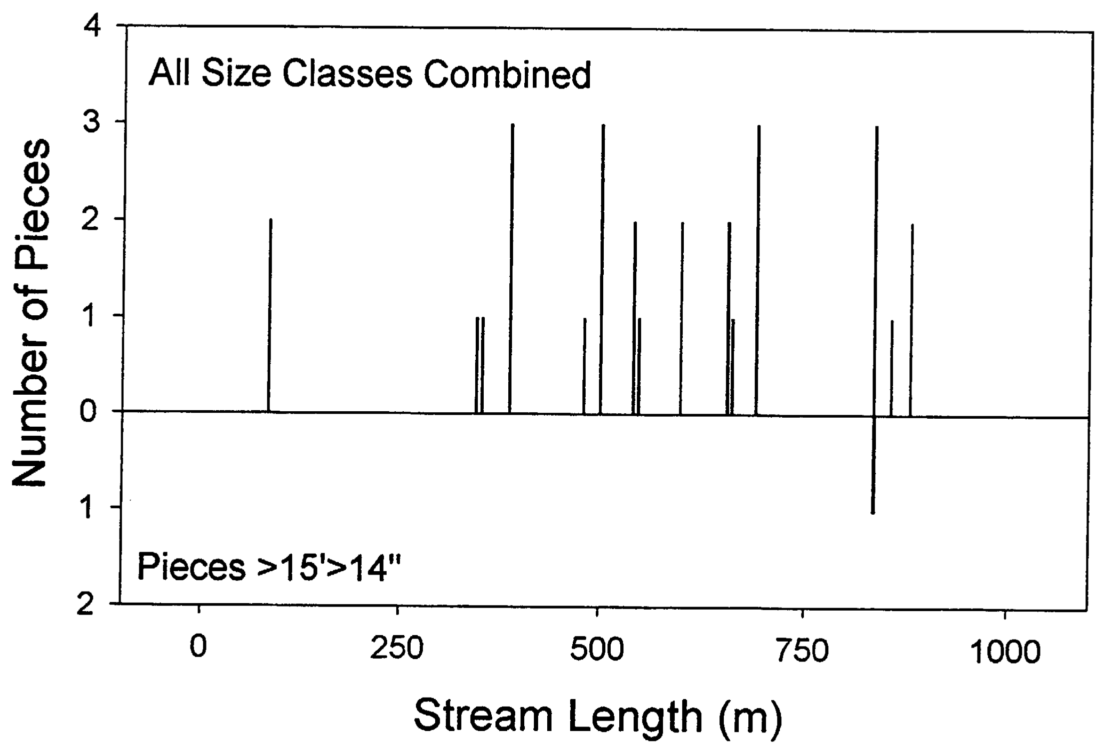

Figure 25. Distribution and total abundance of large woody debris in the right fork of Red Creek.

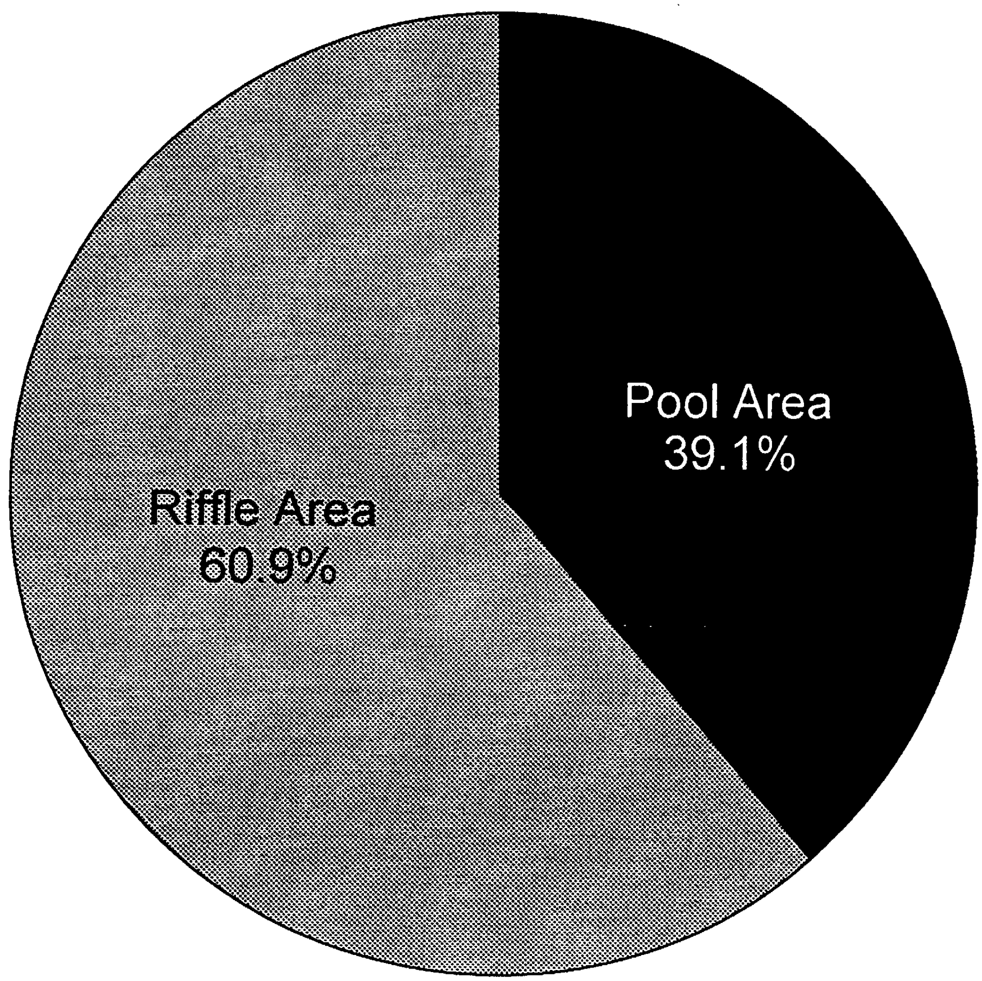

Figure 26. Percent of pool and riffle area in Left Fork Red Creek.

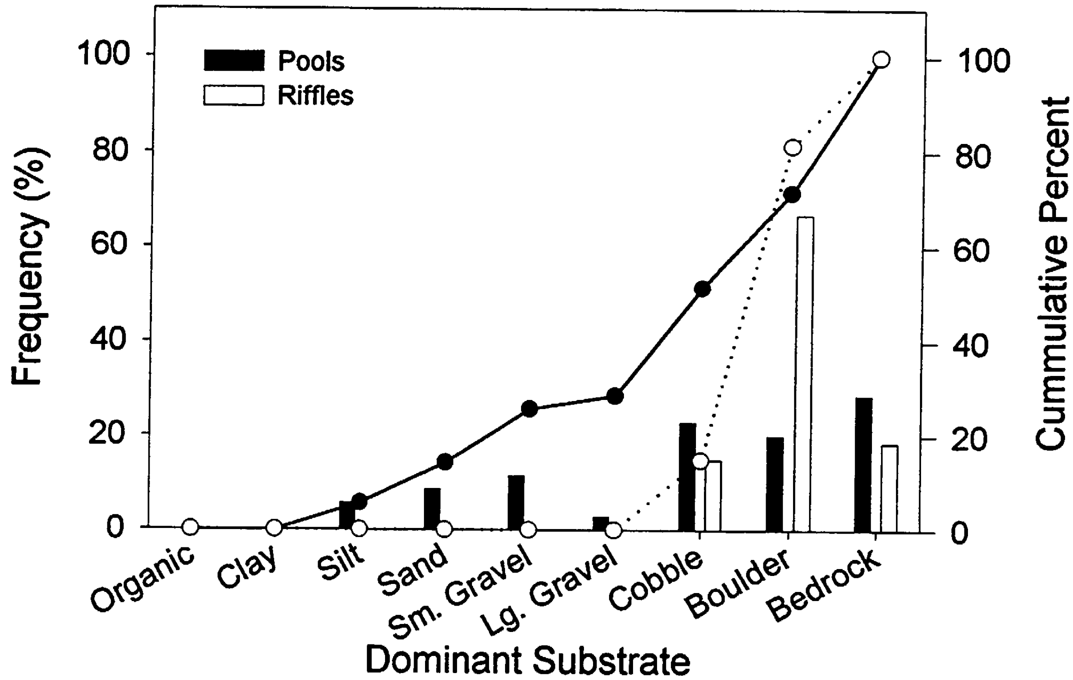

Figure 27. Frequency (percent) of dominant substrate occurrence by habitat type in Left Fork Red Creek. Solid dots represent cumulative percent of pools and open dots represent cumulative percent of riffles.

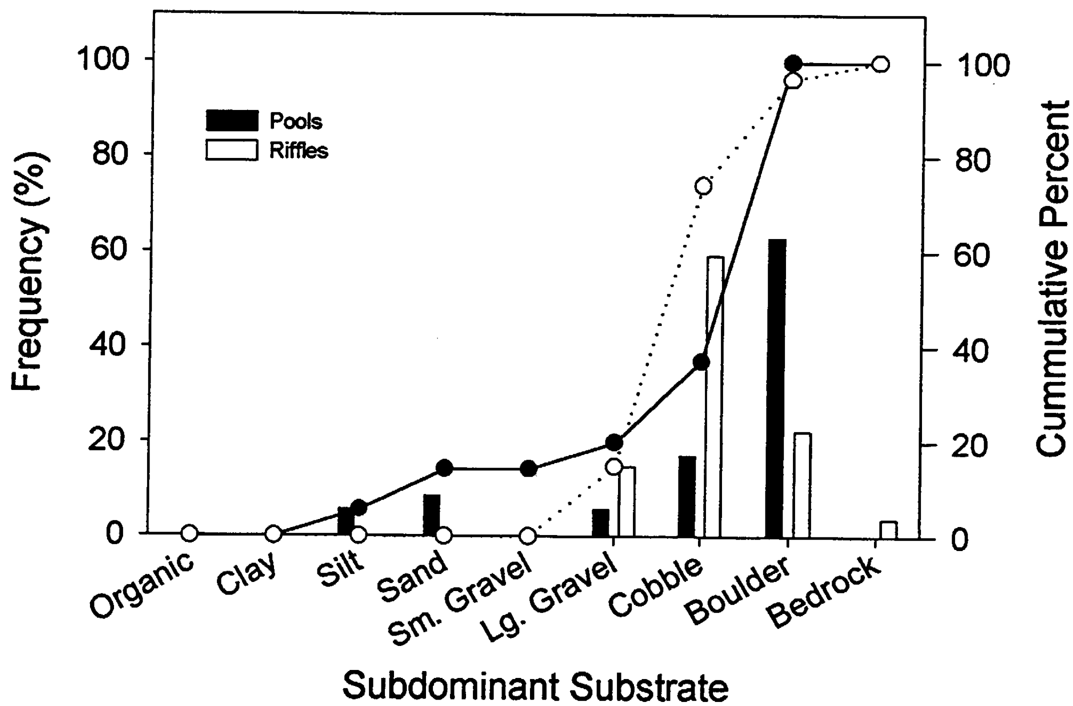

Figure 28. Frequency (percent) of subdominant substrate occurrence by habitat type in Left Fork Red Creek. Solid dots represent cumulative percent of pools and open dots represent cumulative percent of riffles.

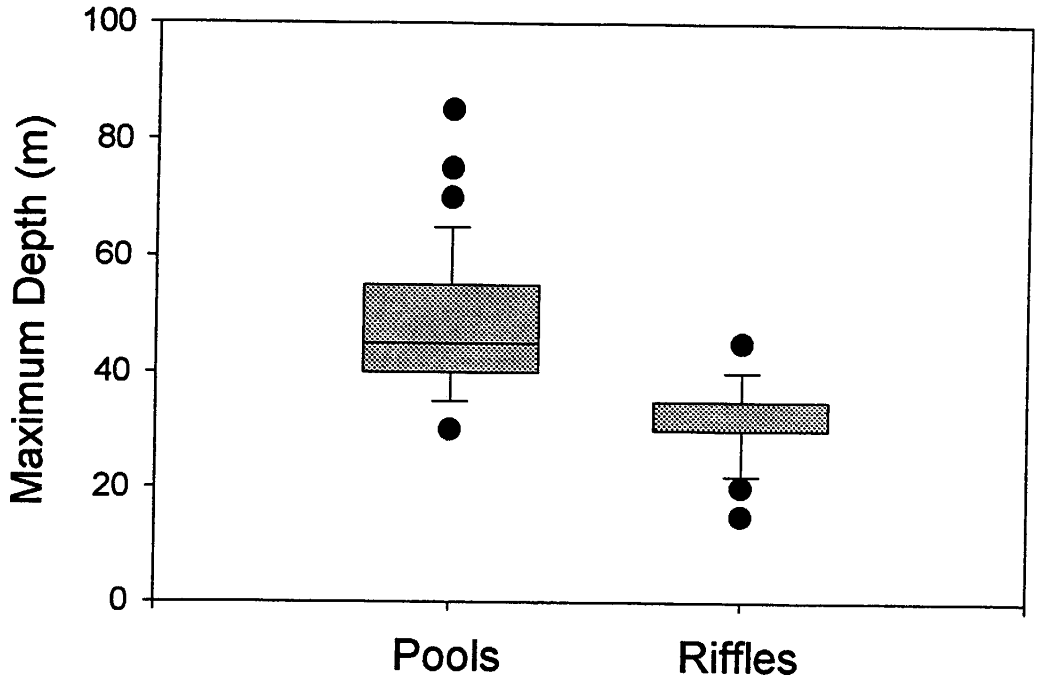

Figure 29. Box plots for habitat-unit maximum depth in Left Fork Red Creek. The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

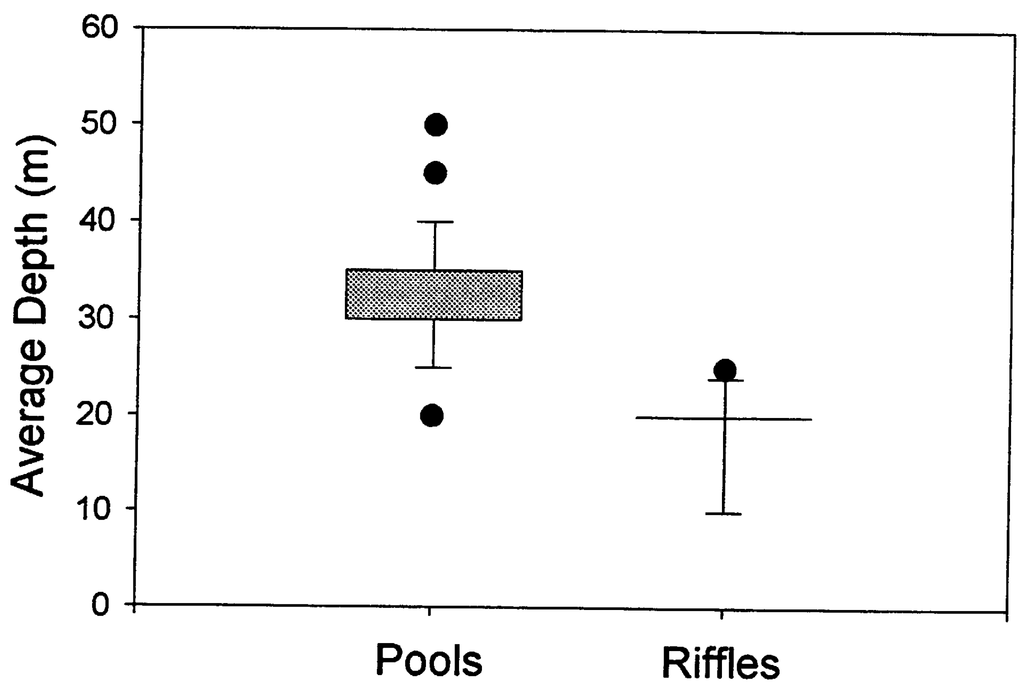

Figure 30. Box plots for habitat-unit average depth in Left Fork Red Creek. The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

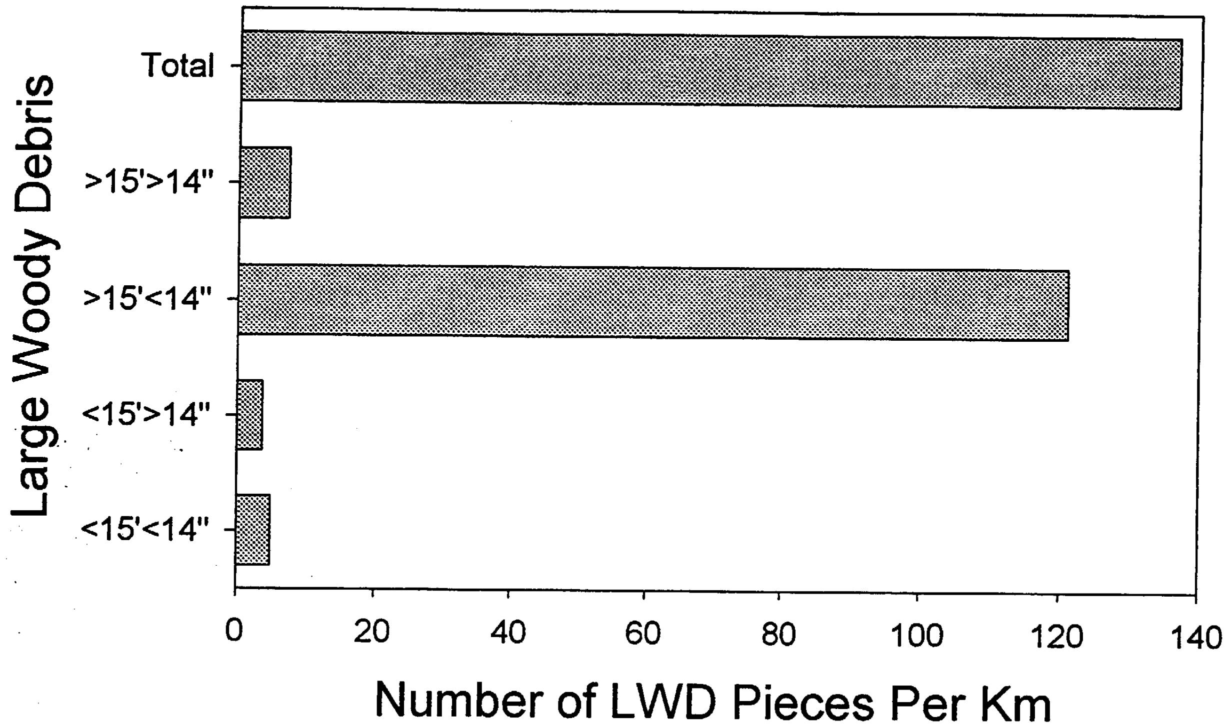

Figure 31. Pieces of large woody debris per kilometer in Left Fork Red Creek.

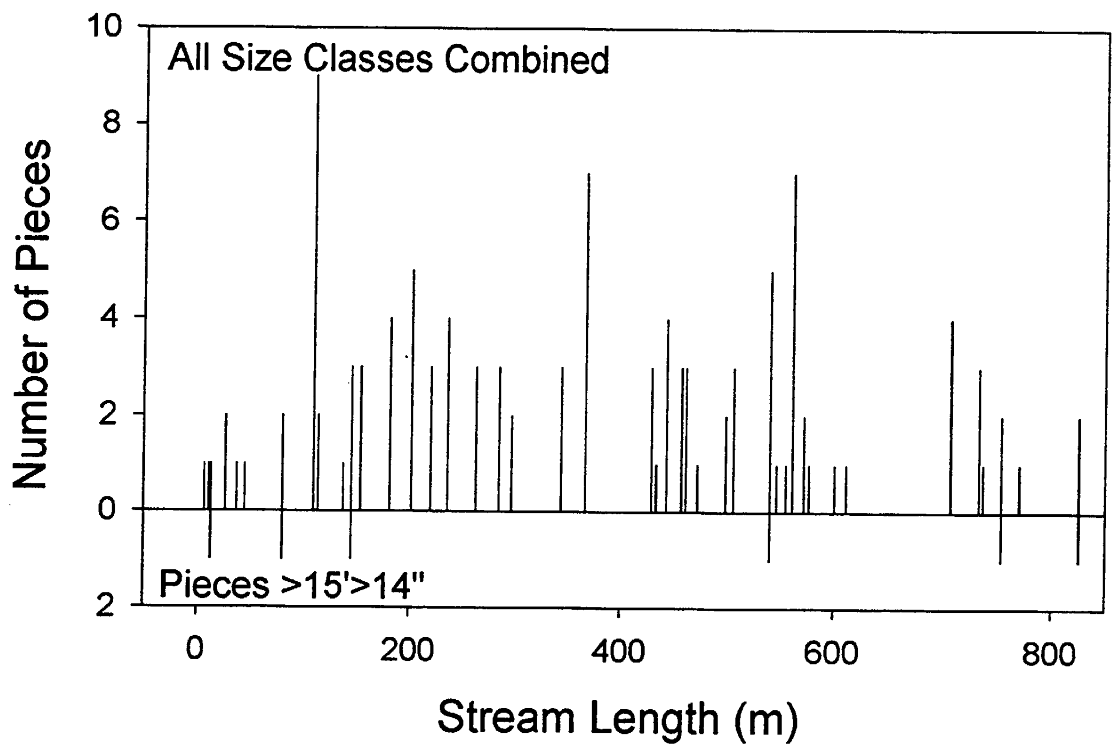

Figure 32. Distribution and total abundance of large woody debris in Left Fork Red Creek.

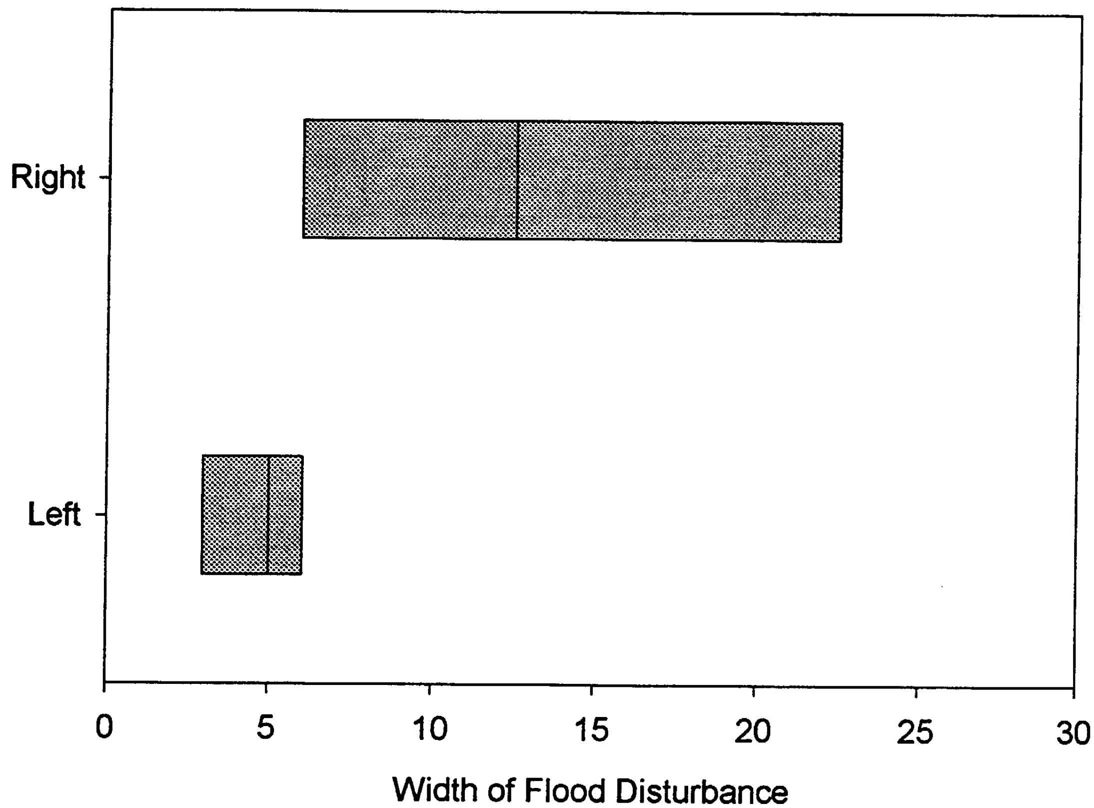

Figure 33. Box plots of visable flood disturbance from the water's edge (right and left sides) in Left Fork Red Creek. The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

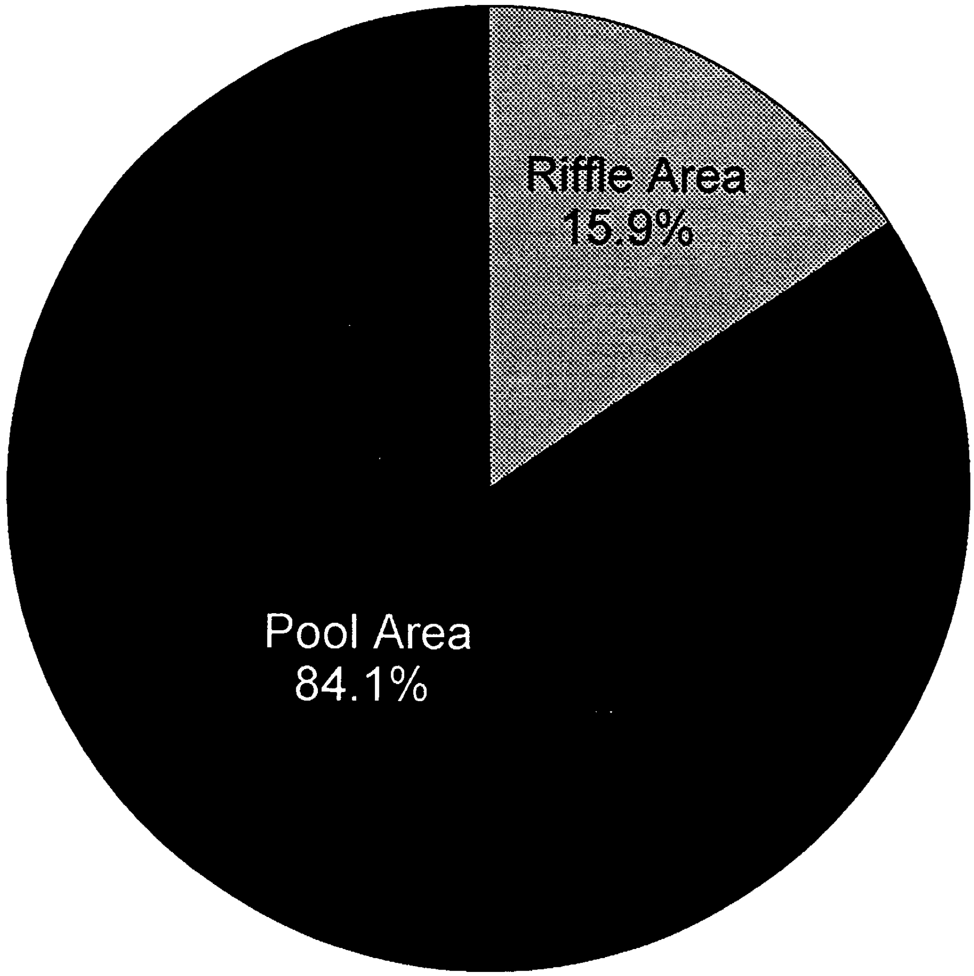

Figure 34. Percent Area of pools and riffle habitat types in Stonecoal Run.

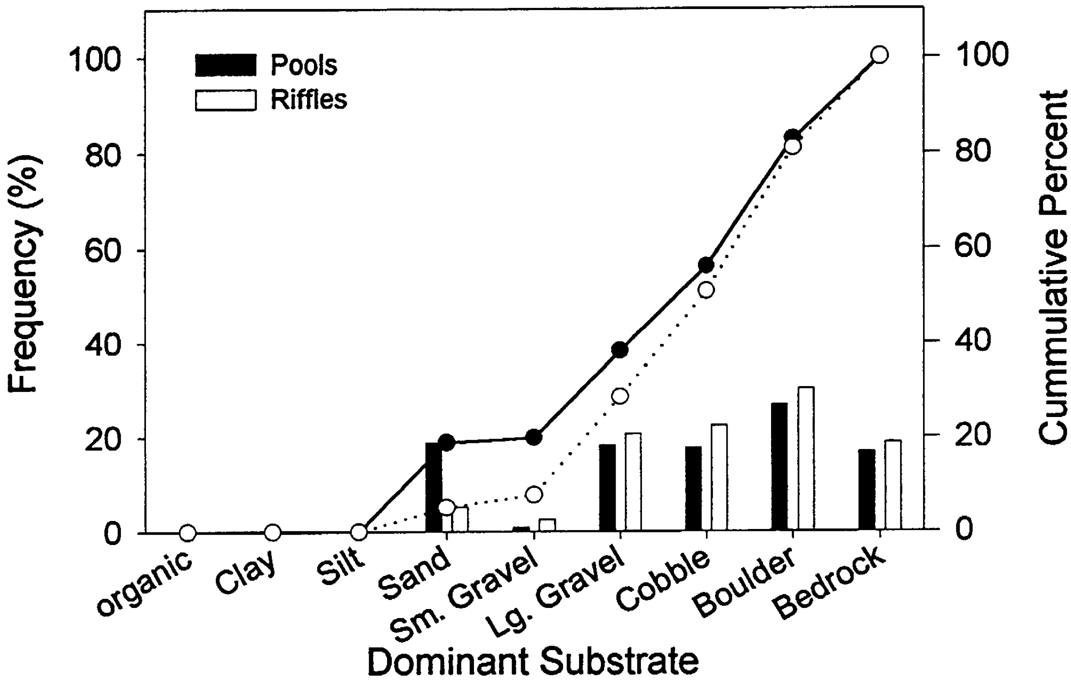

Figure 35. Frequency (percent) of dominant substrate occurrence by habitat type in Stonecoal Run . Solid dots represent cumulative percent of pools and open dots represent cumulative percent of riffles.

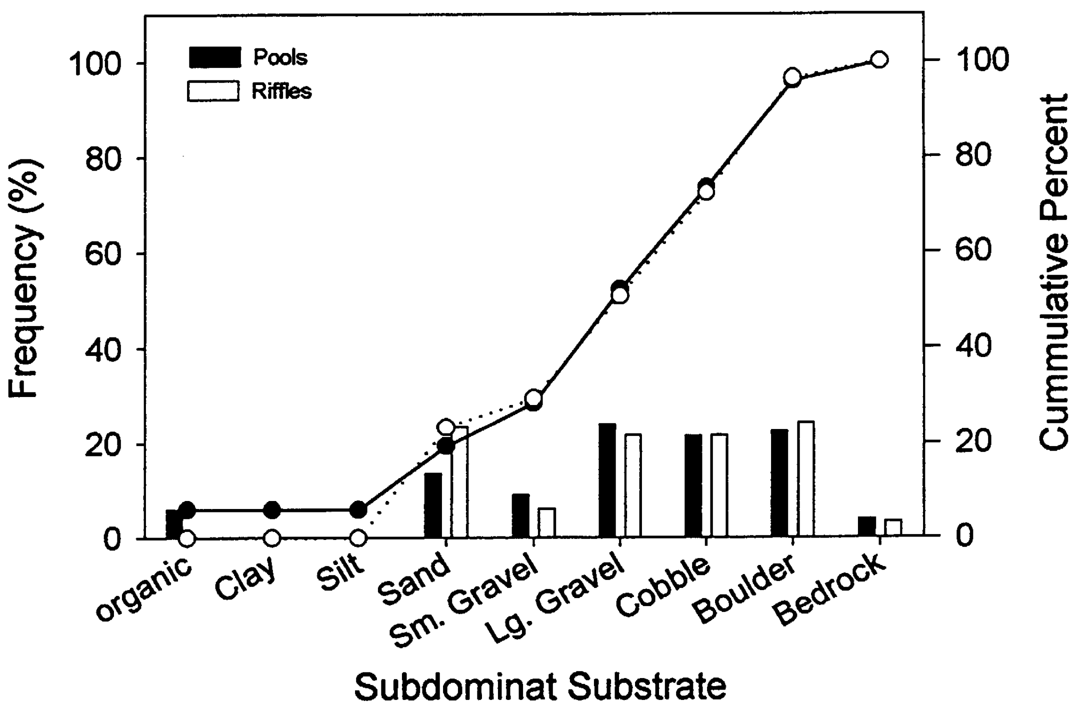

Figure 36. Frequency (percent) of subdominant substrate occurrence by habitat type in Stonecoal Run. Solid dots represent cumulative percent of pools and open dots represent cumulative percent of riffles.

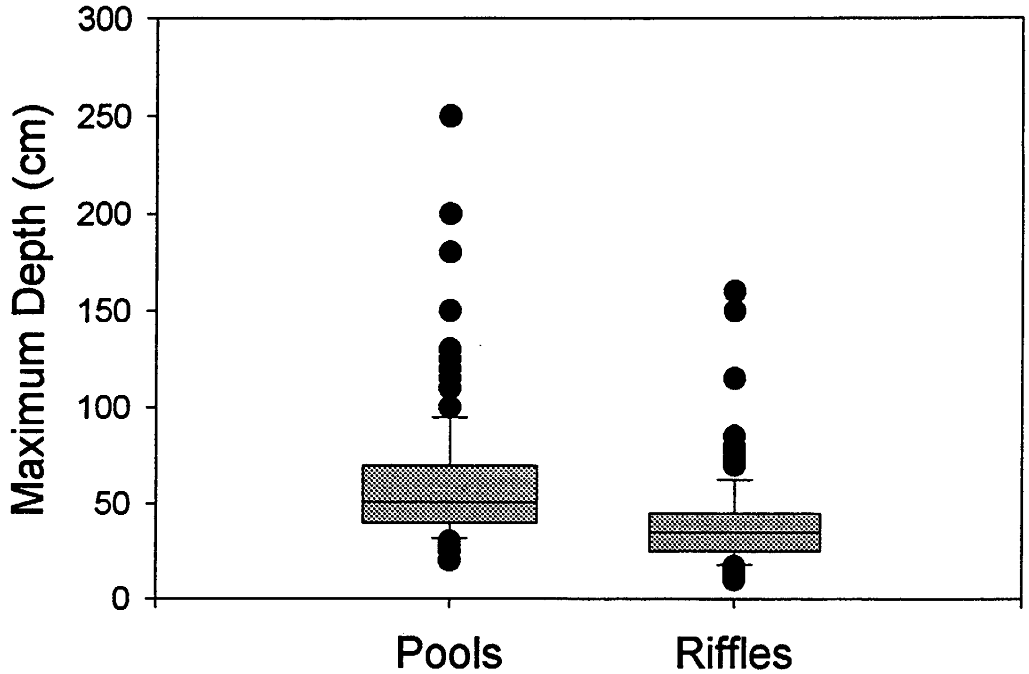

Figure 37. Box plots for habitat-unit maximum depth in Stonecoal Run.
The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

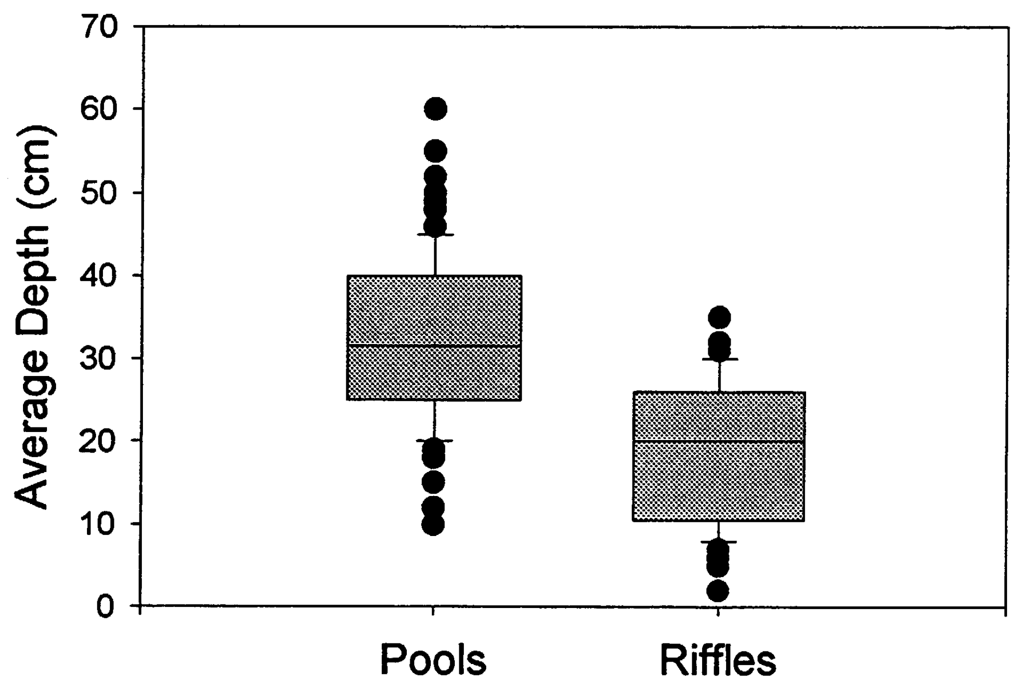

Figure 38. Box plots for habitat-unit average depth in Stonecoal Run.
The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

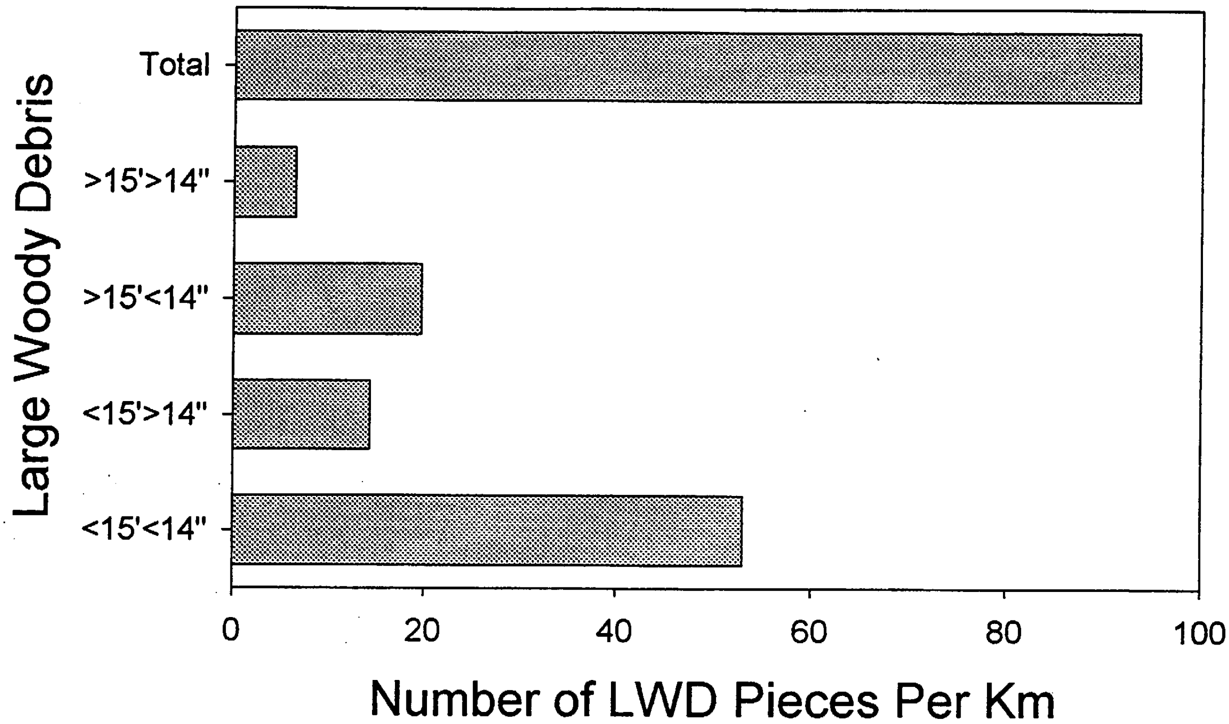

Figure 39. Pieces of large woody debris per kilometer in Stonecoal Run.

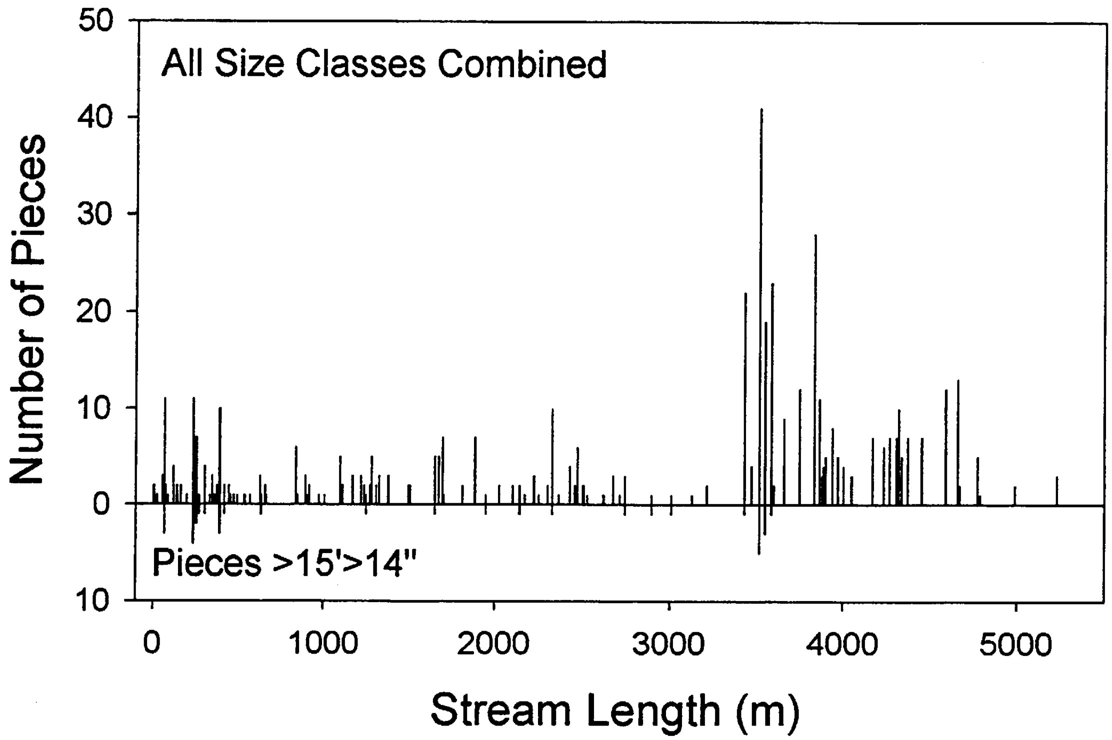

Figure 40. Distribution and total abundance of large woody debris in Stonecoal Run.

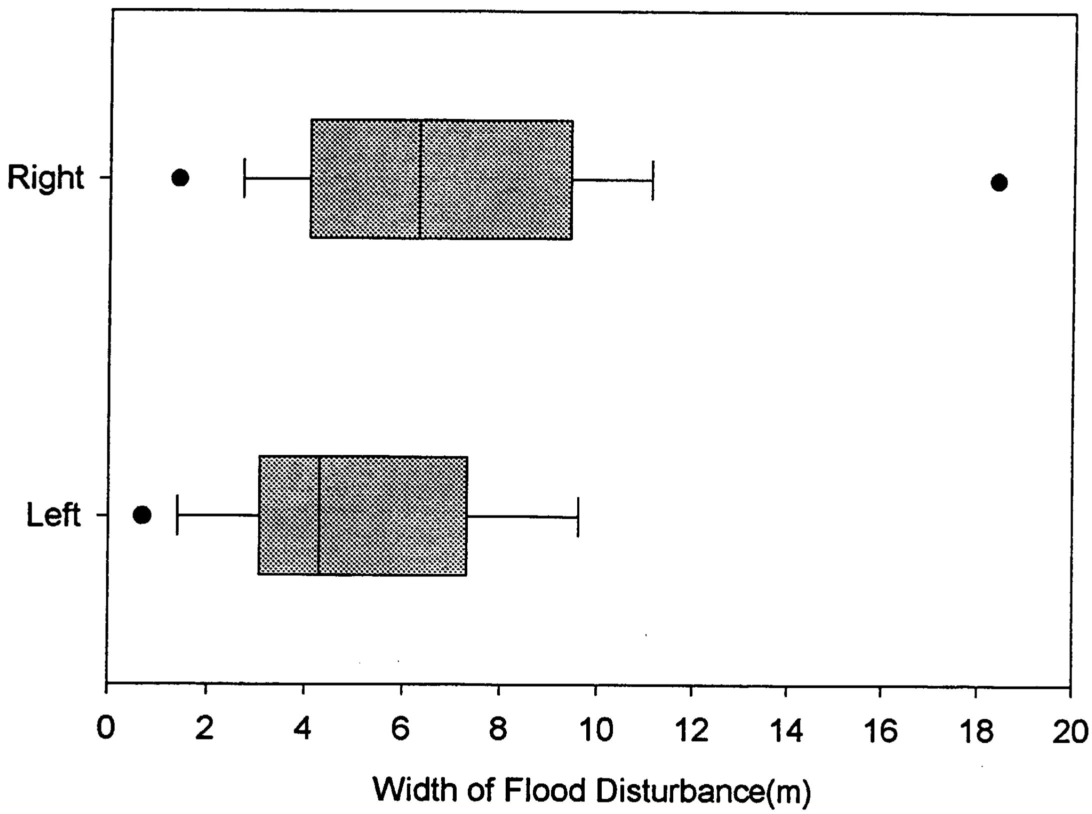

Figure 41. Box plots of visable flood disturbance from the water's edge (right and left sides) in Stonecoal Run. The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

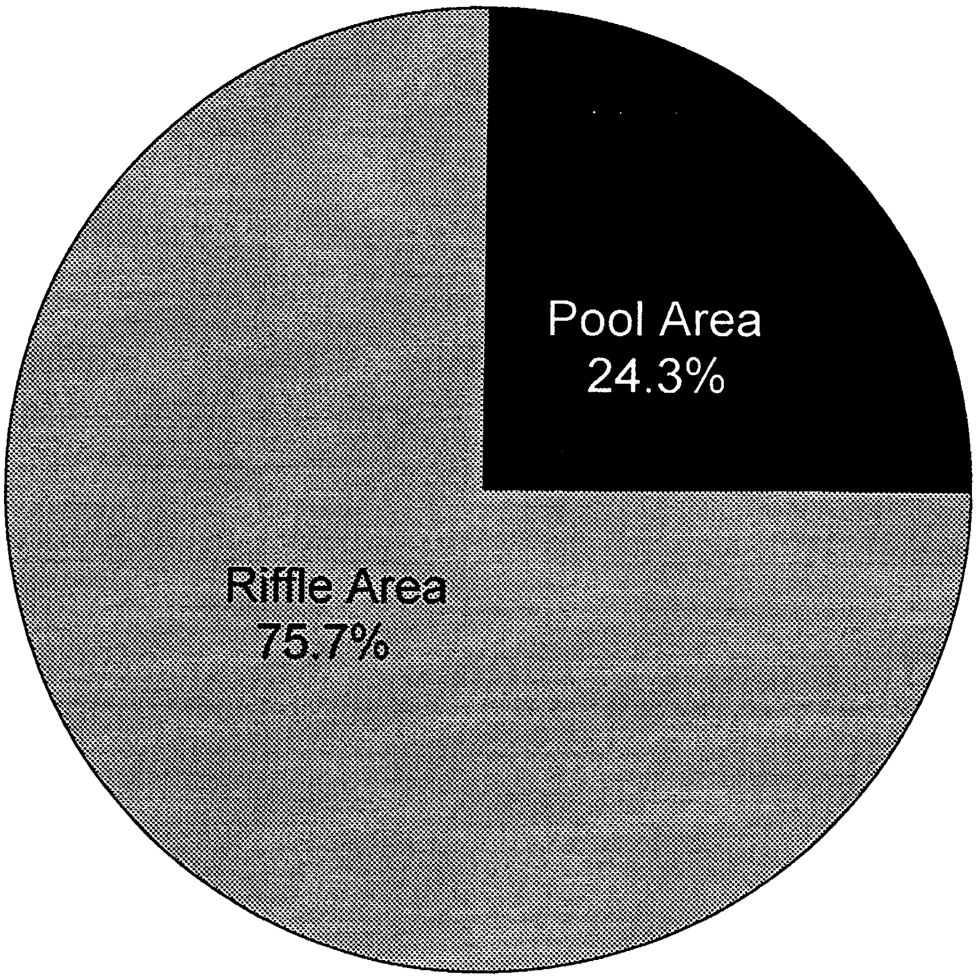

Figure 42. Percent of pool and riffle area in Fisher Spring Run.

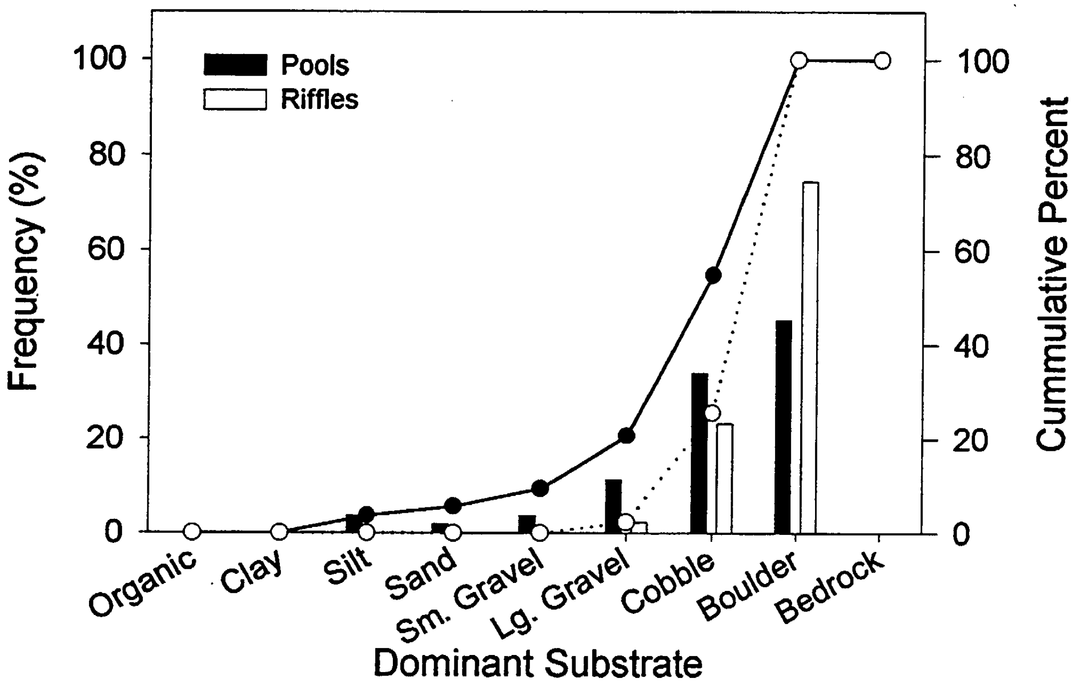

Figure 43. Frequency (percent) of dominant substrate occurrence by habitat type in Fisher Spring Run. Solid dots represent cumulative percent of pools and open dots represent cumulative percent of riffles.

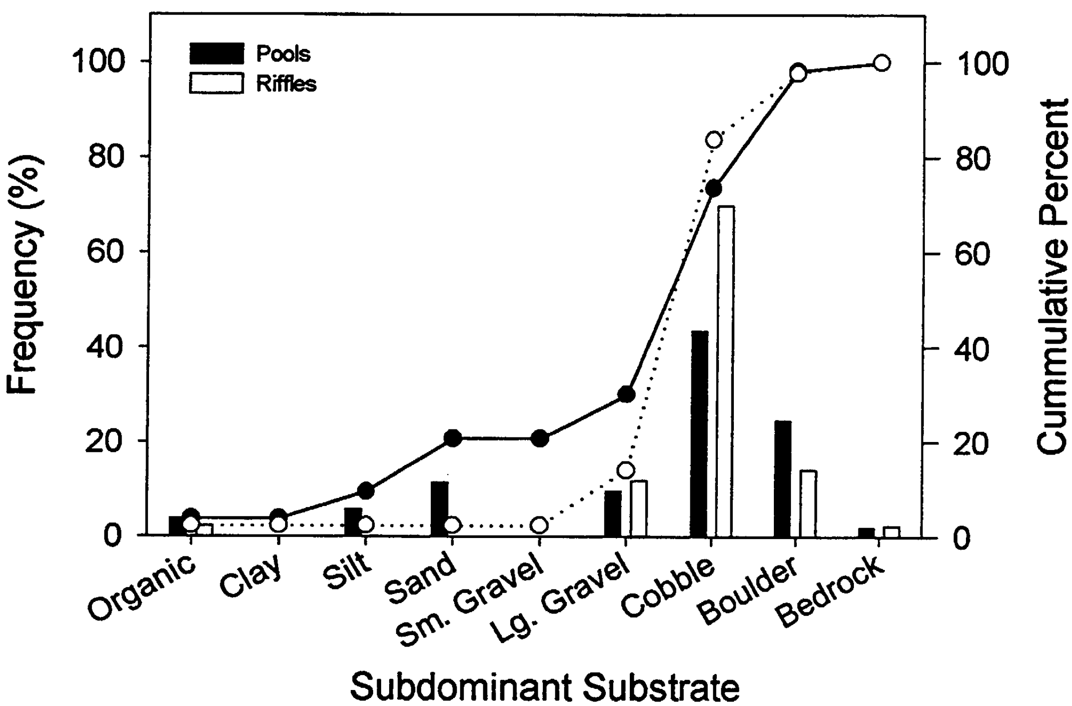

Figure 44. Frequency (percent) of subdominant substrate occurrence by habitat type in Fisher Spring Run. Solid dots represent cumulative percent of pools and open dots represent cumulative percent of riffles.

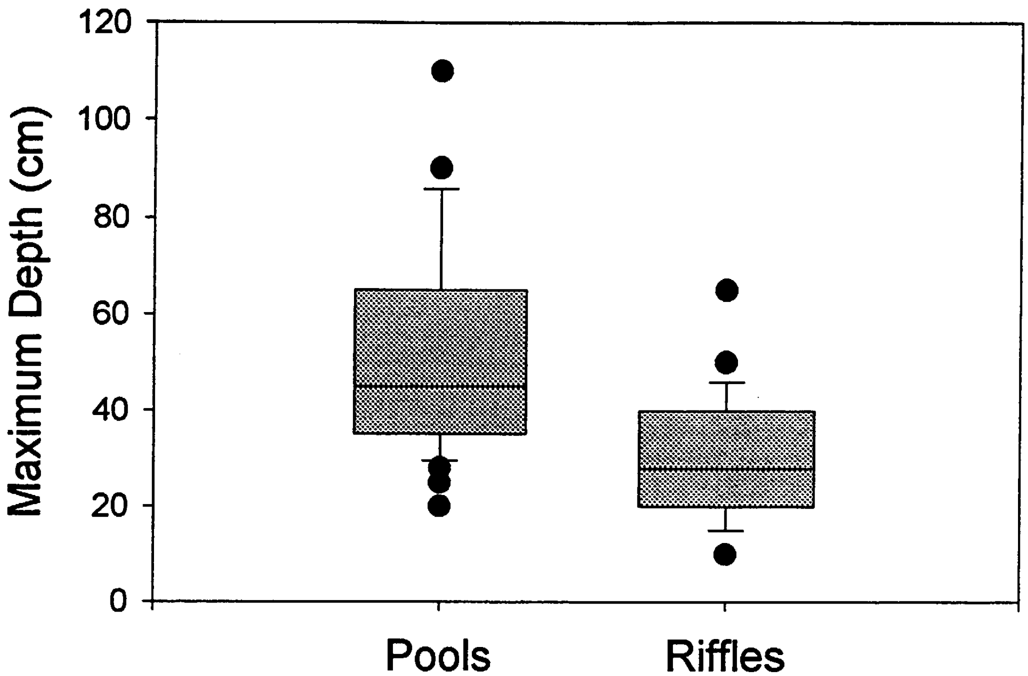

Figure 45. Box plots for habitat-unit maximum depth in Fisher Spring Run.
The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

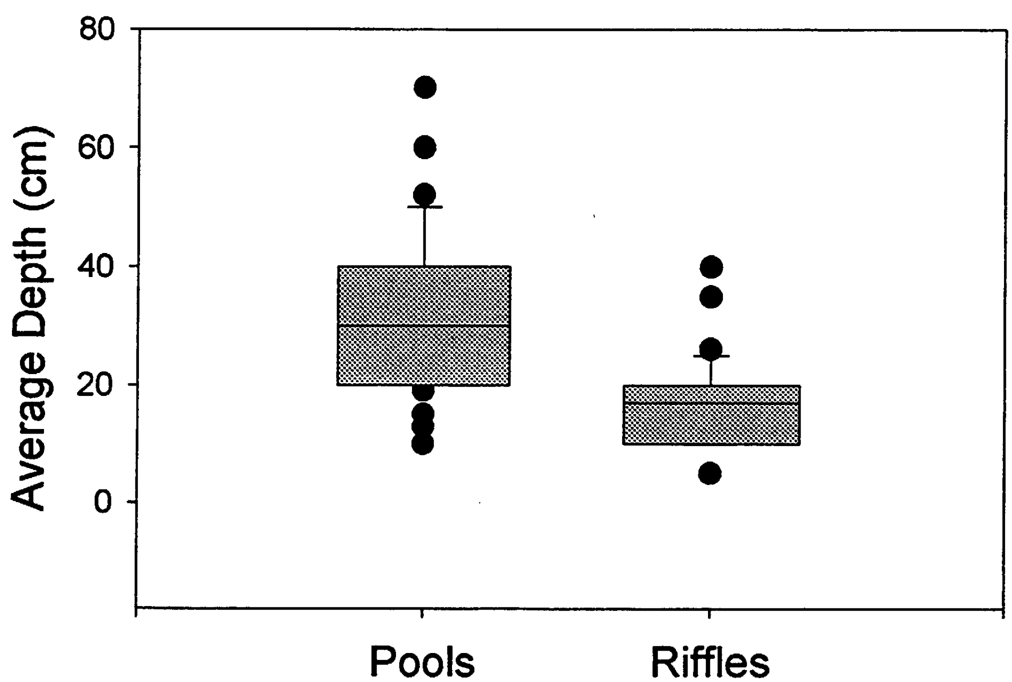

Figure 46. Box plots for habitat-unit average depth in Fisher Spring Run.
The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

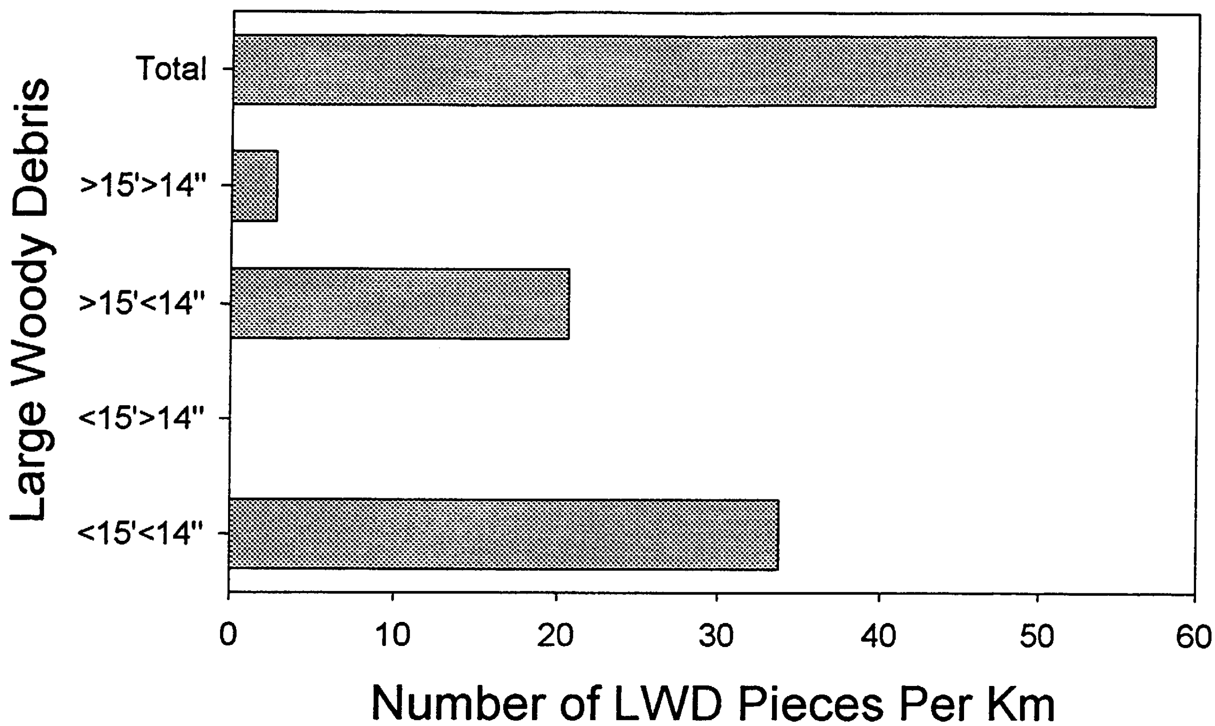

Figure 47. Pieces of large woody debris per kilometer in Fisher Spring Run.

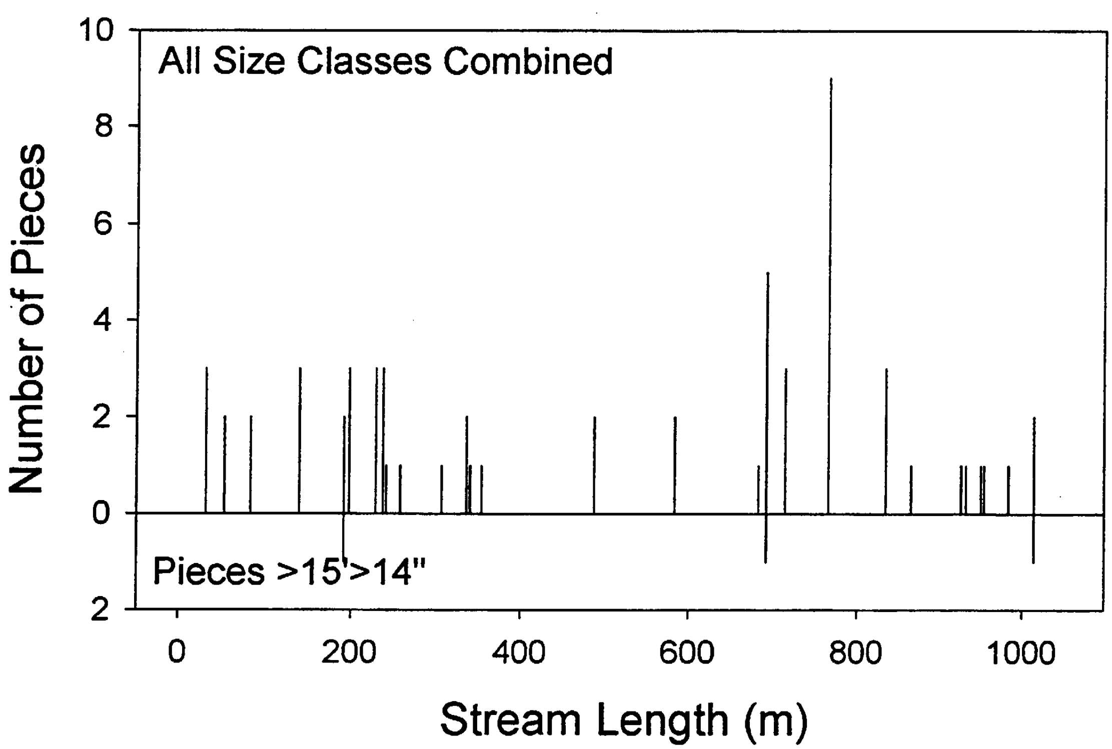

Figure 48. Distribution and total abundance of large woody debris in Fisher Spring Run.

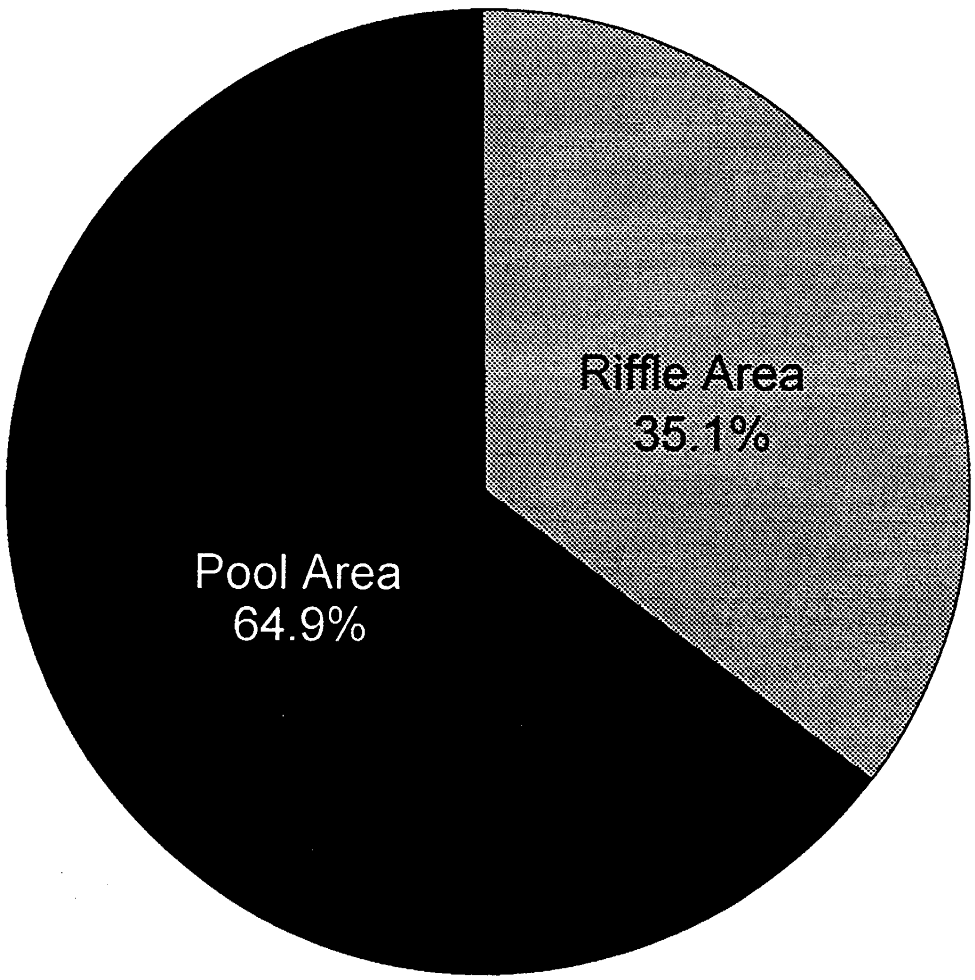

Figure 49. Percent of pool and riffle area in the lower unnamed tributary.

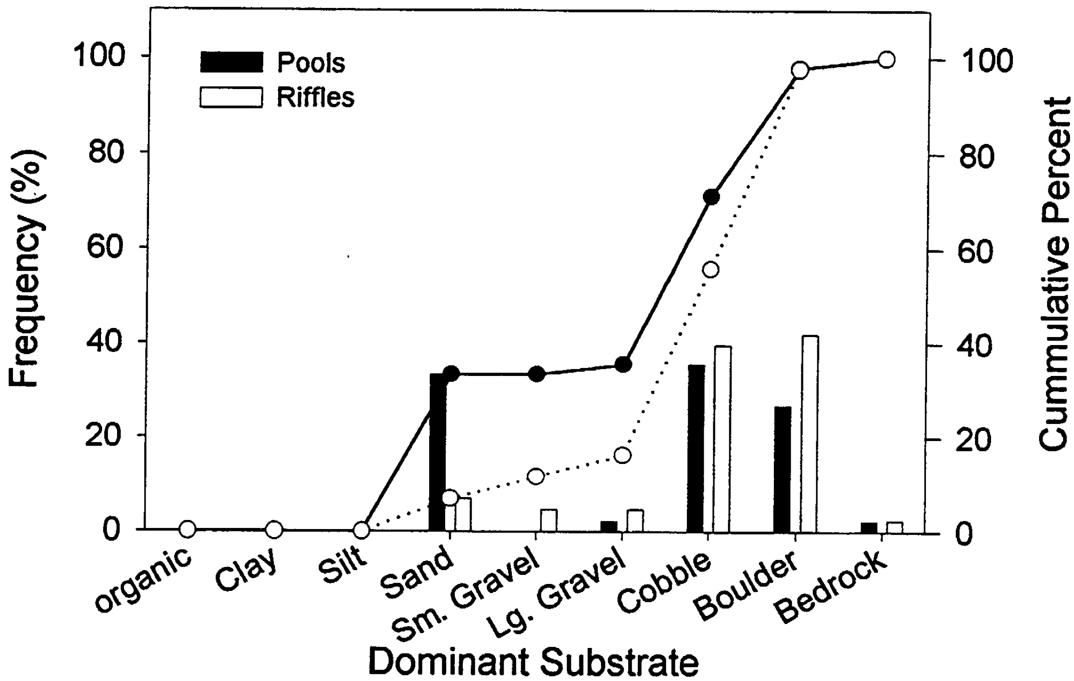

Figure 50. Frequency (percent) of dominant substrate occurrence by habitat type in the lower unnamed tributary. Solid dots represent cumulative percent of pools and open dots represent cumulative percent of riffles.

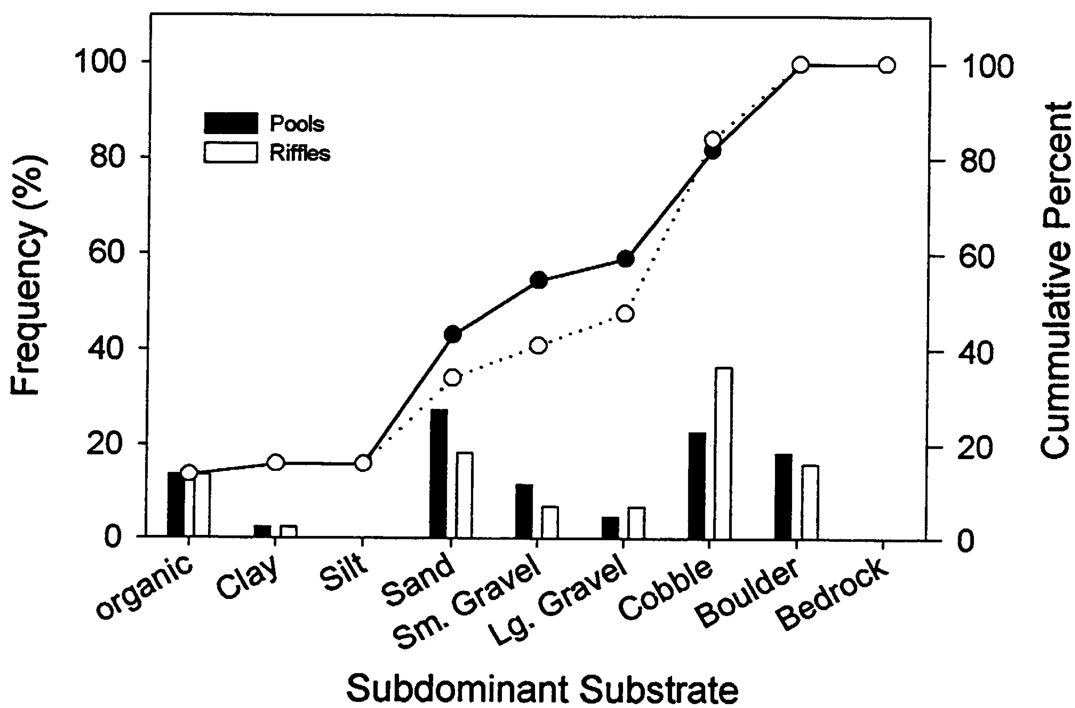

Figure 51. Frequency (percent) of subdominant substrate occurrence by habitat type in the lower unnamed tributary. Solid dots represent cumulative percent of pools and open dots represent cumulative percent of riffles.

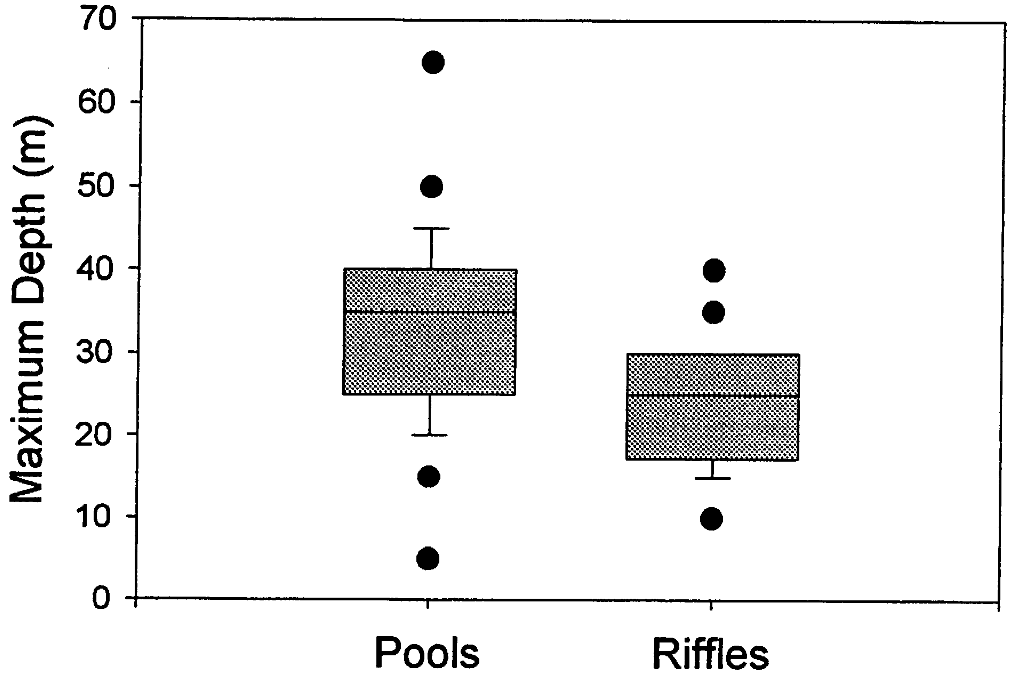

Figure 52. Box plots for habitat-unit maximum depth in the lower unnamed tributary. The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

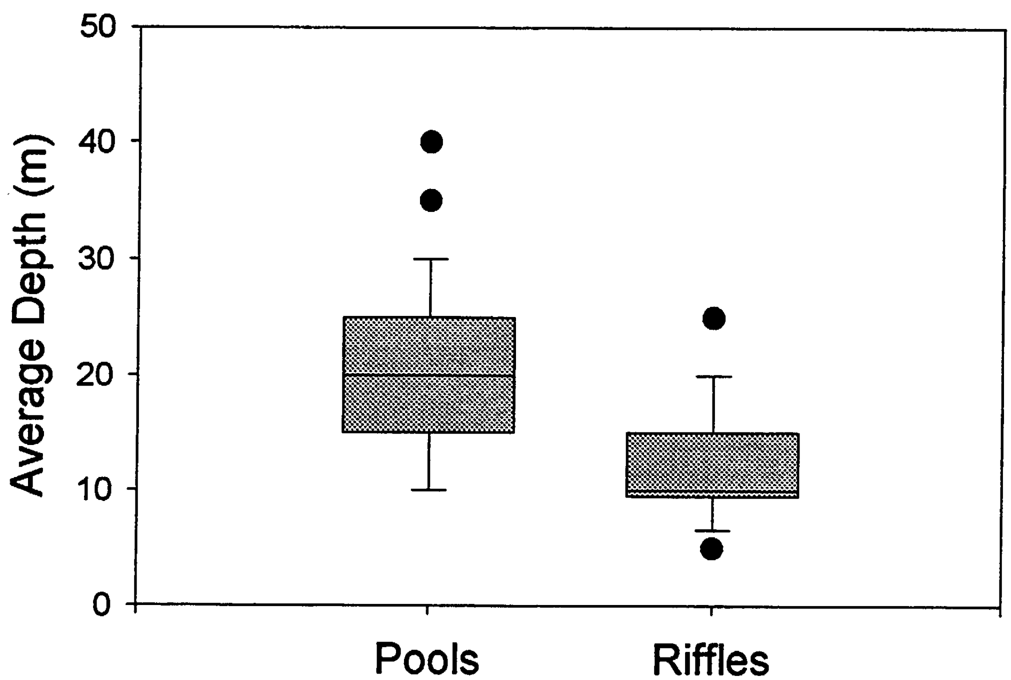

Figure 53. Box plots for habitat-unit average depth in the lower unnamed tributary. The box encloses the middle 50% of the observations, the capped lines below and above the box represent the 10% and 90% quantiles, respectively, dots represent outliers and the solid line in the box represents the median.

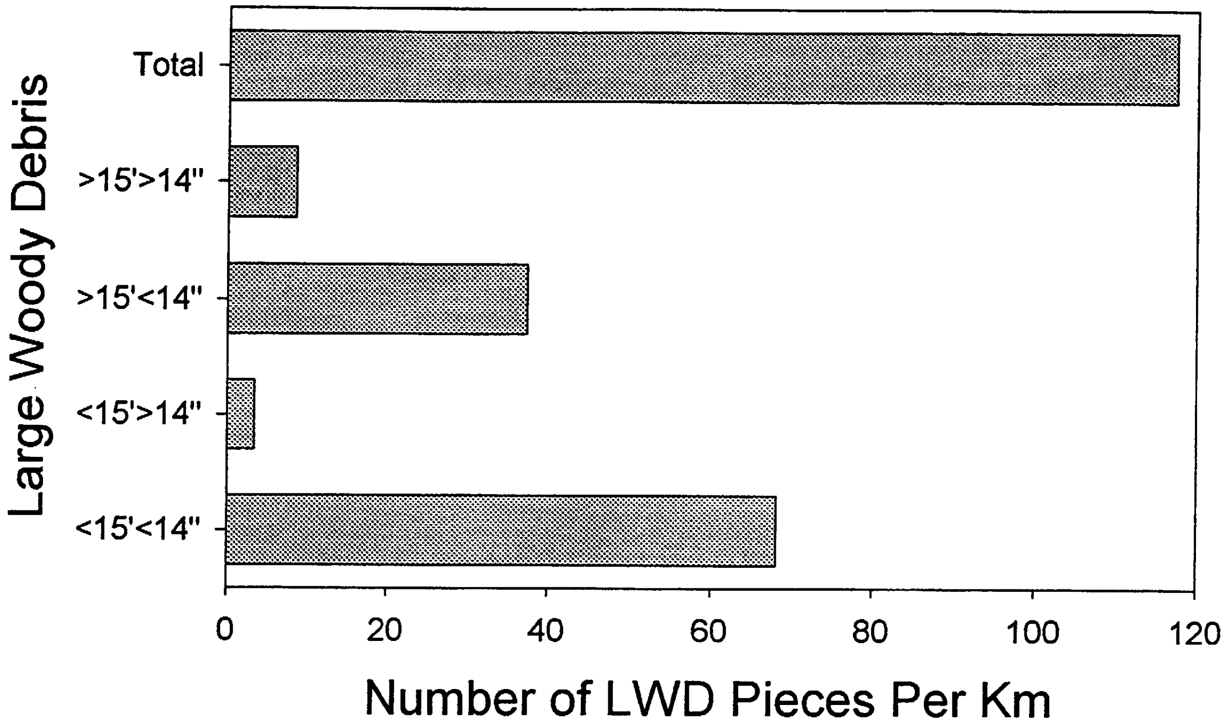

Figure 54. Pieces of large woody debris per kilometer in the lower unnamed tributary.

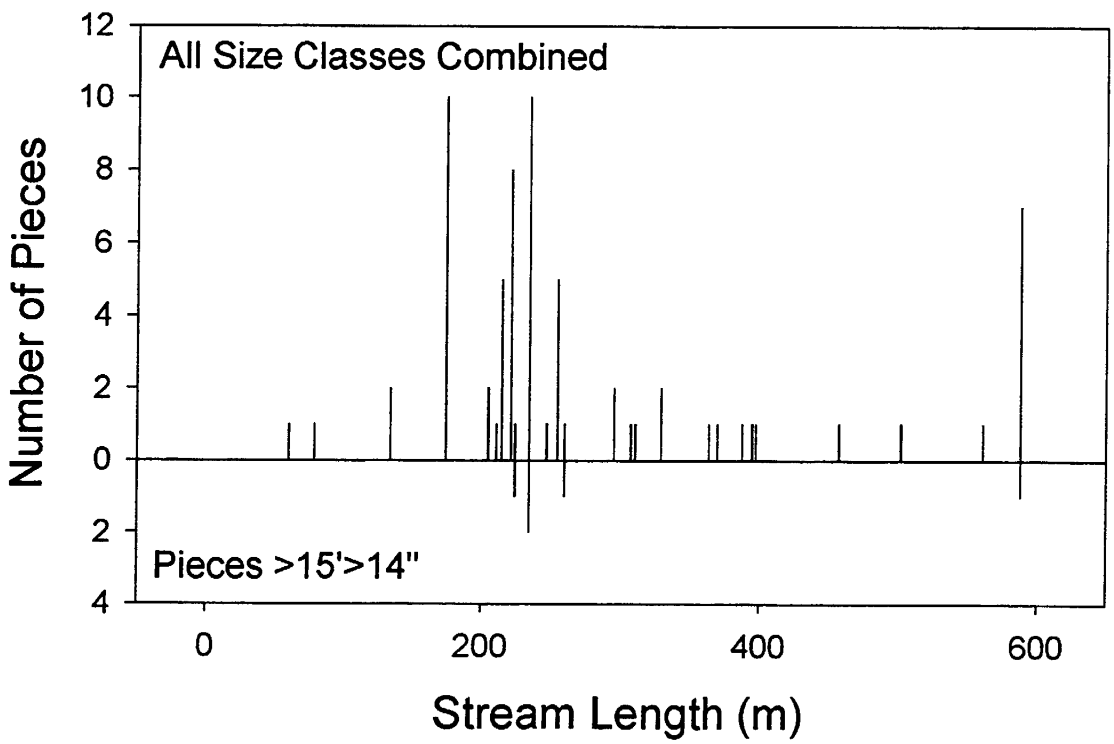

Figure 55. Distribution and total abundance of large woody debris in the lower unnamed tributary.

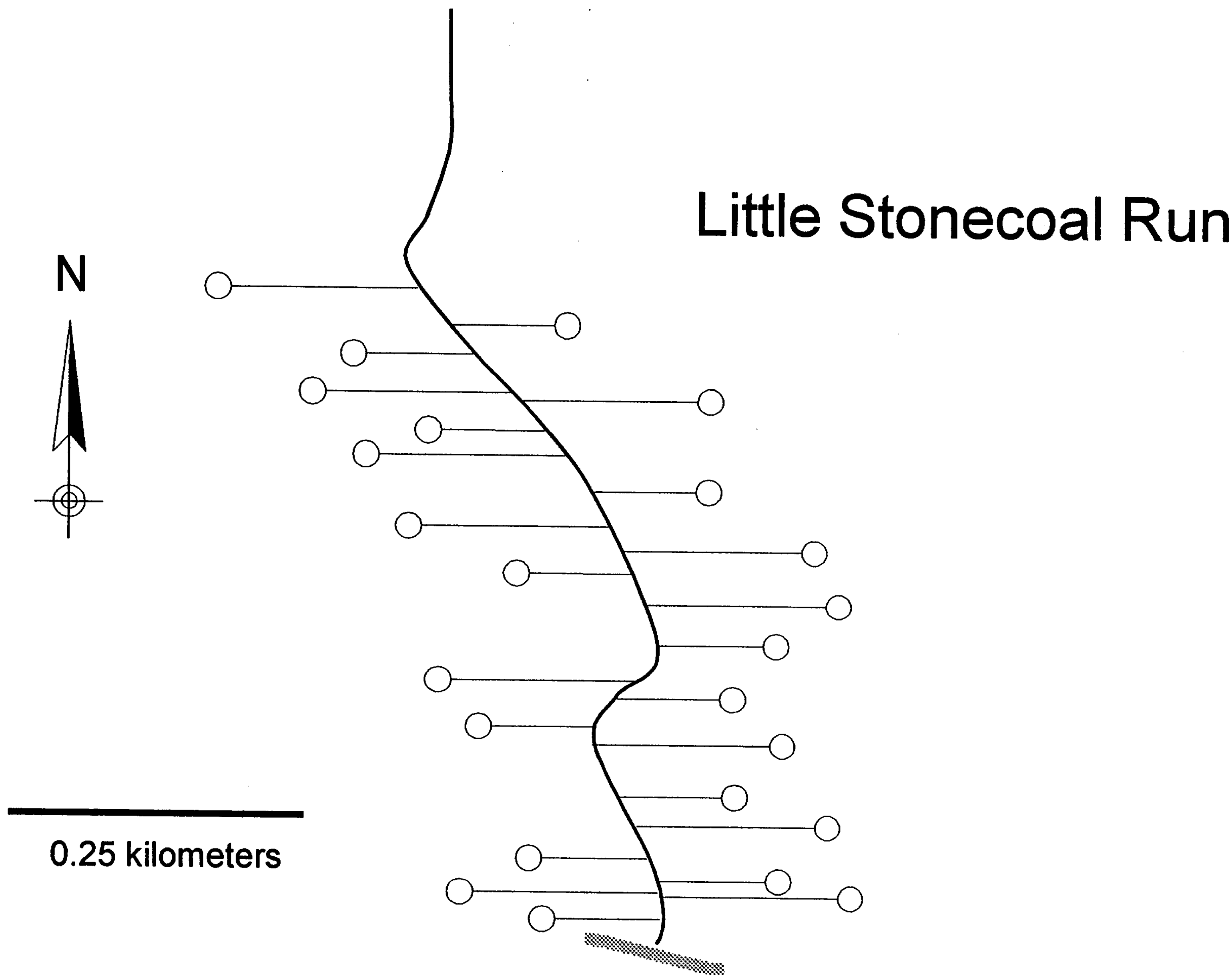

Figure 56. Circles represent habitat units sampled in Little Stonecoal Run using underwater observation.

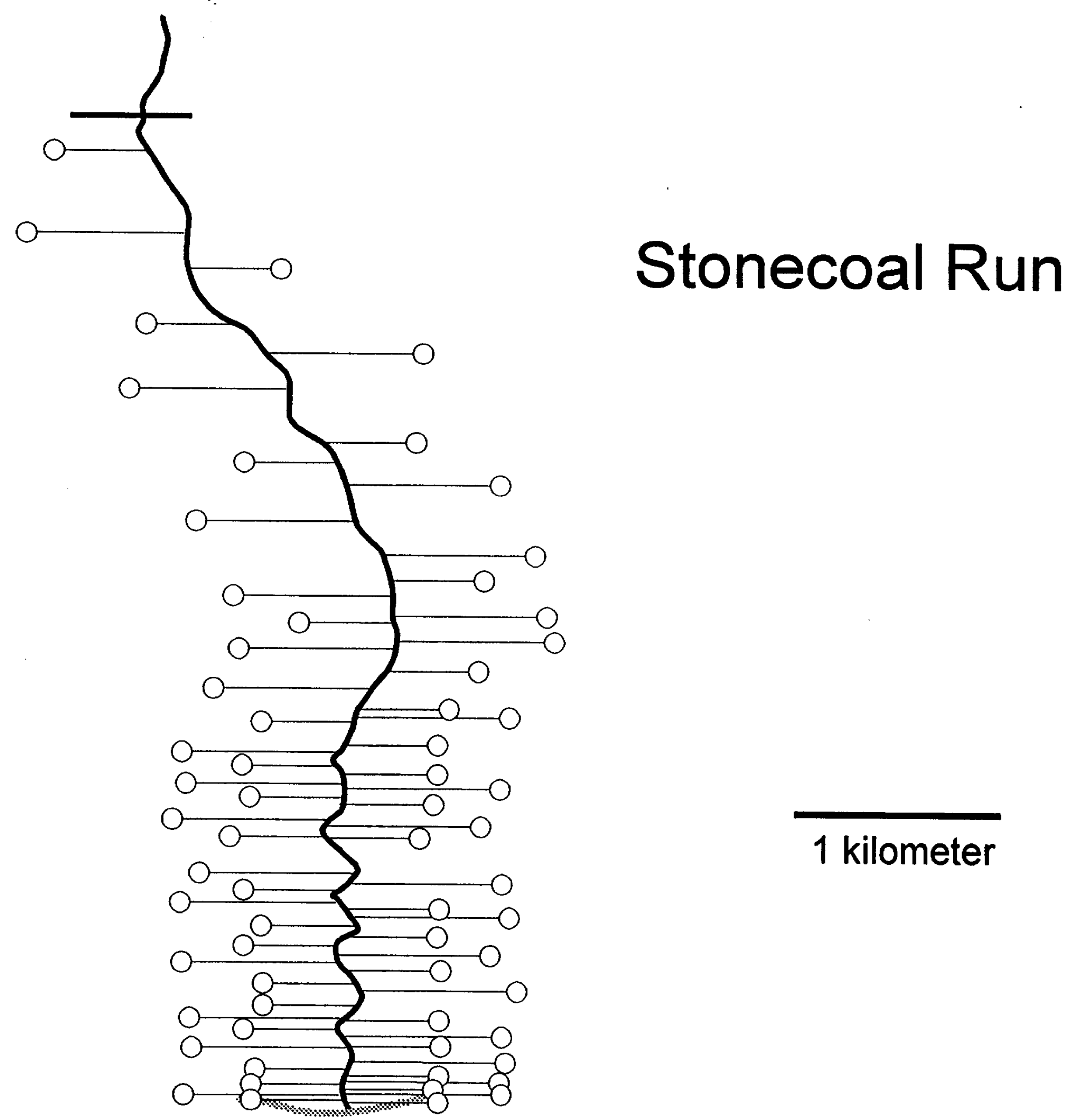

Figure 57. Circles represent habitat units sampled for fish in Stonecoal Run. Using underwater observation and electrofishing.

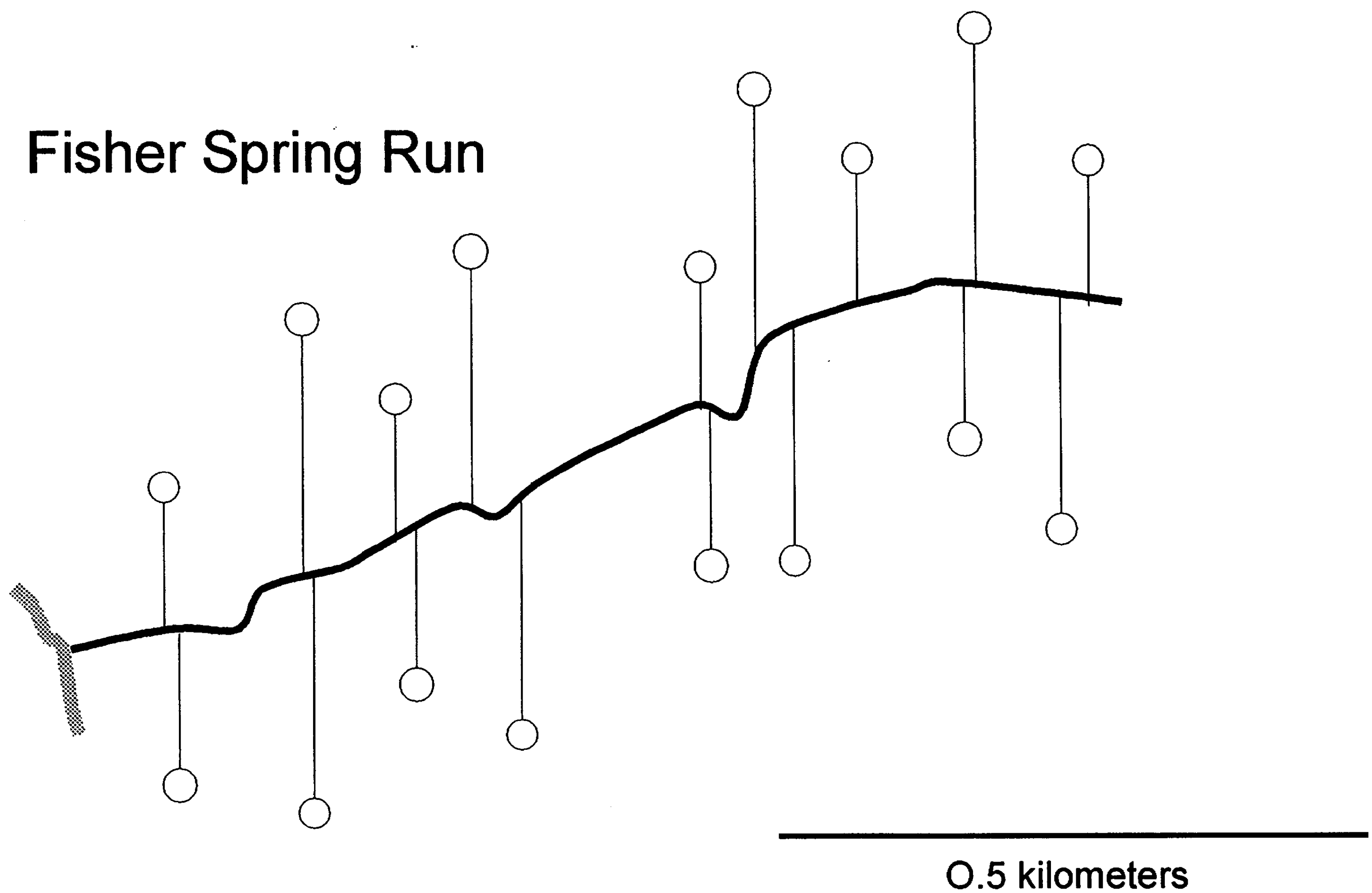

Figure 58. Circles represent units sampled for fish in Fisher Spring Run using both underwater observation and electrofishing.

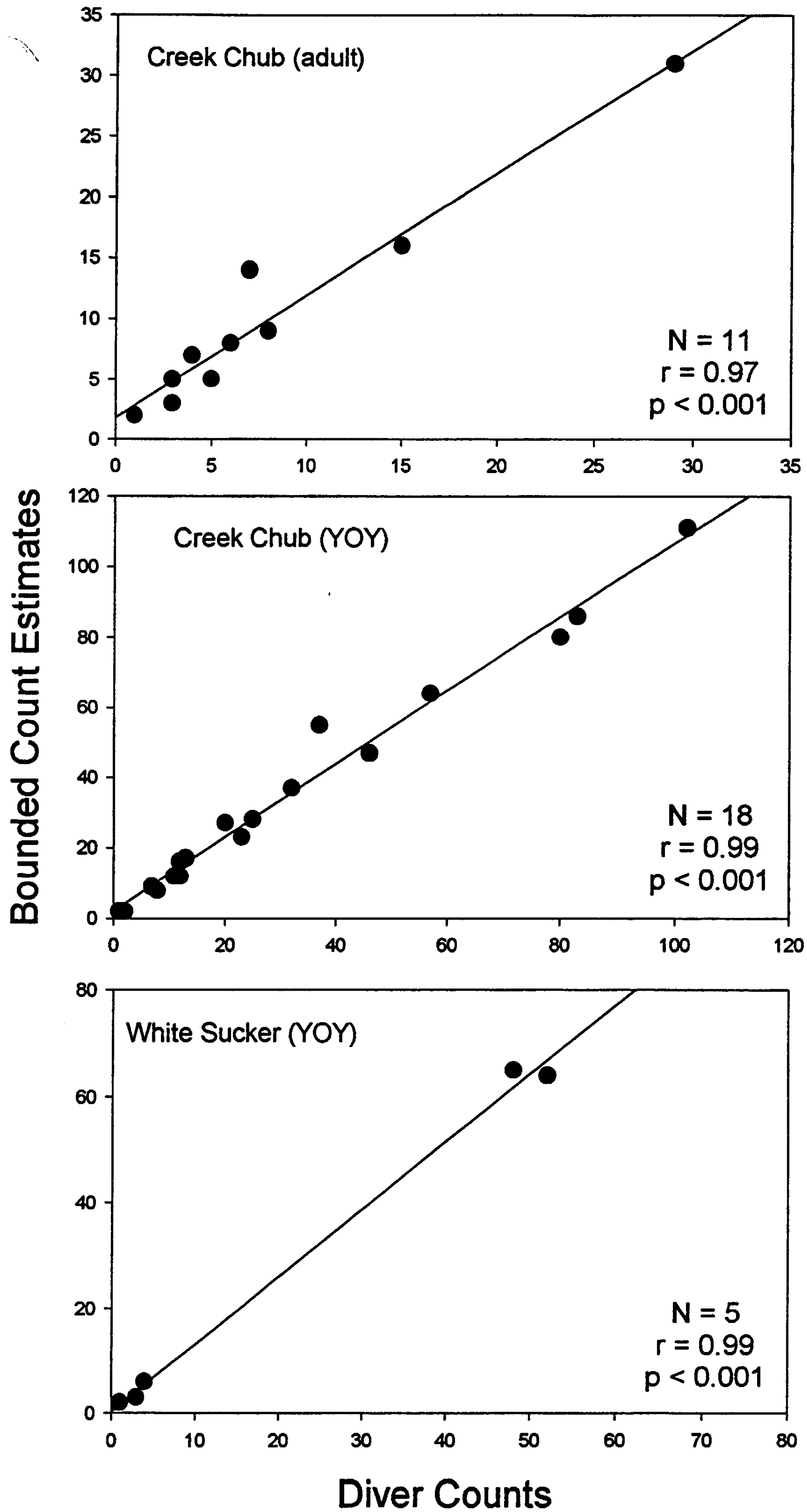

Figure 59. The three graphs show the relationship between the bounded count estimates and the actual diver counts in the main stem of Red Creek for creek chub (adults), creek chub (YOY), and white sucker (YOY).

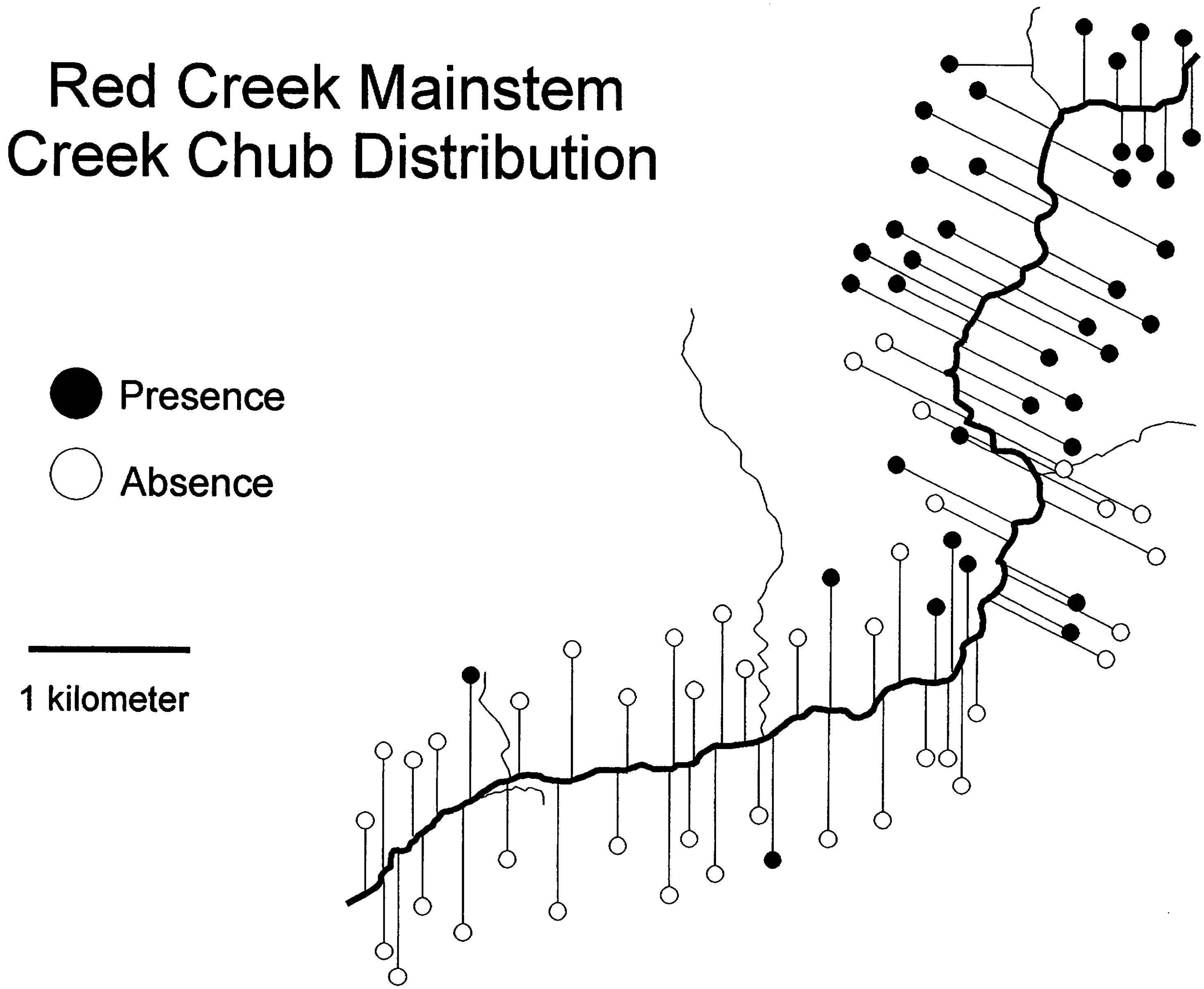

Figure 60. Distribution of creek chub in the Red Creek Watershed study area. Circles indicate sample sites. Solid circles represent sites where creek chubs were present.

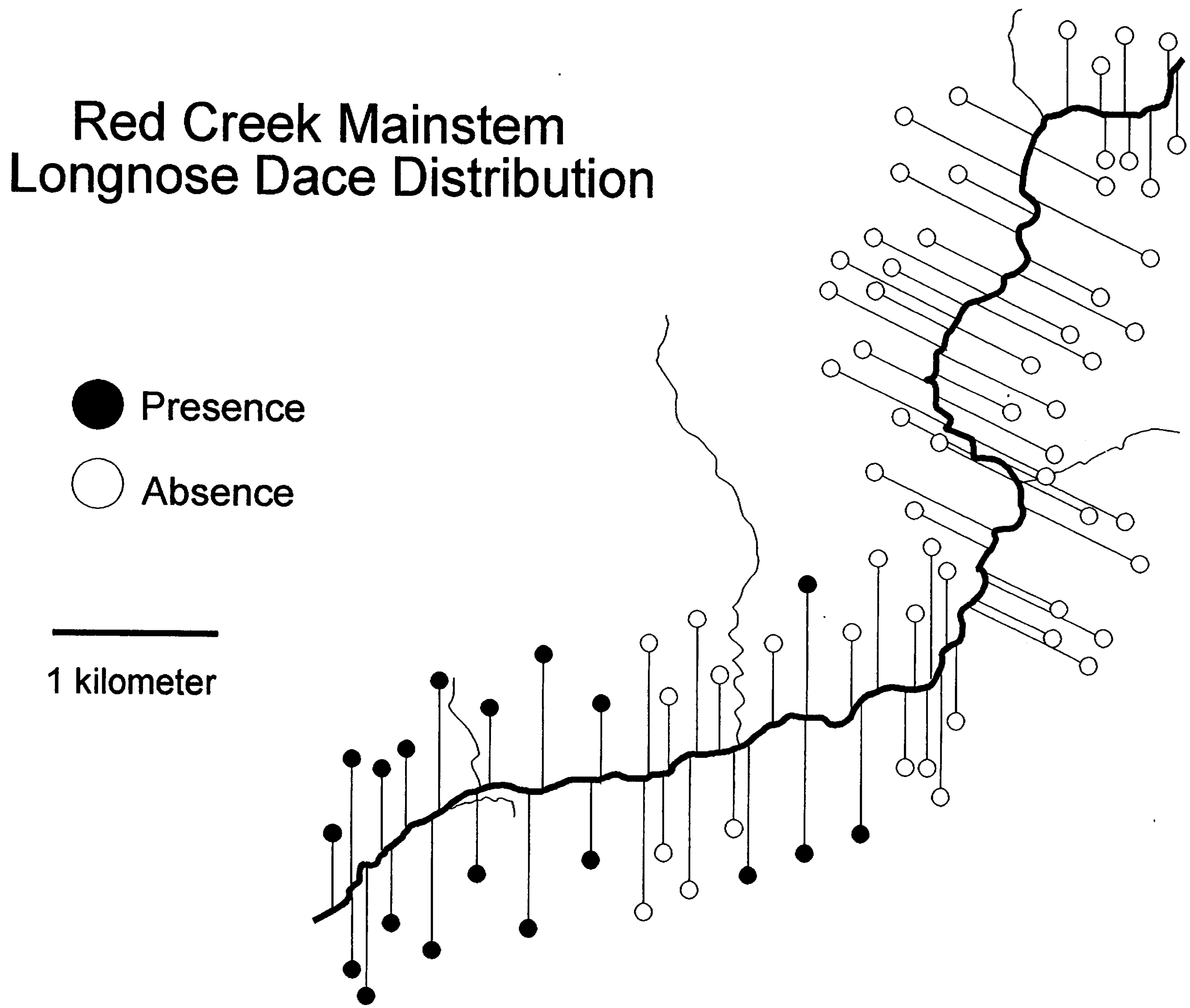

Figure 61. Distribution of longnose dace in the Red Creek Watershed study area. Circles indicate sample sites. Solid circles represent sites where longnose dace were present.

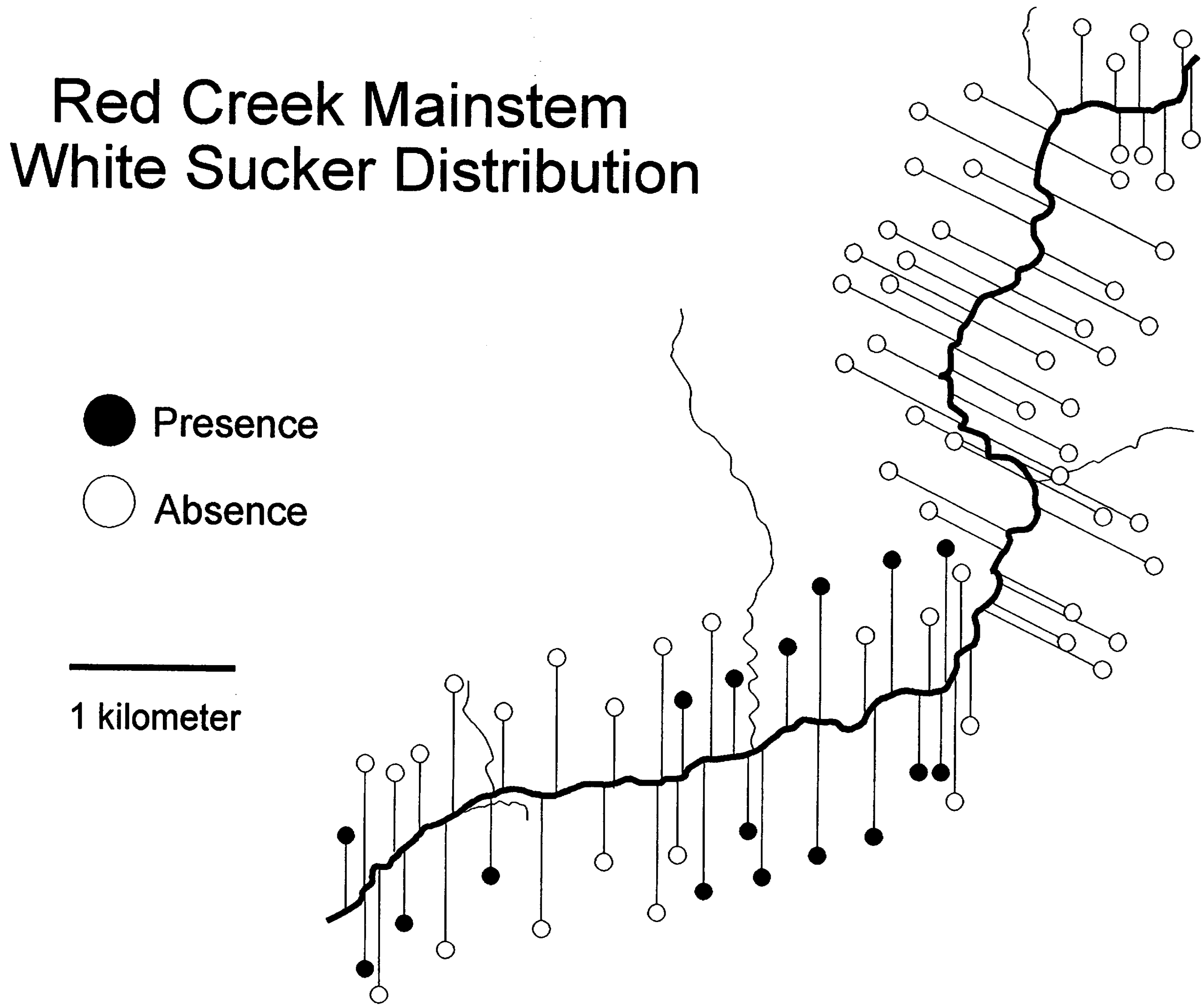

Figure 62. Distribution of white sucker in the Red Creek Watershed study area. Circles indicate sample sites. Solid circles represent sites where white suckers were present.

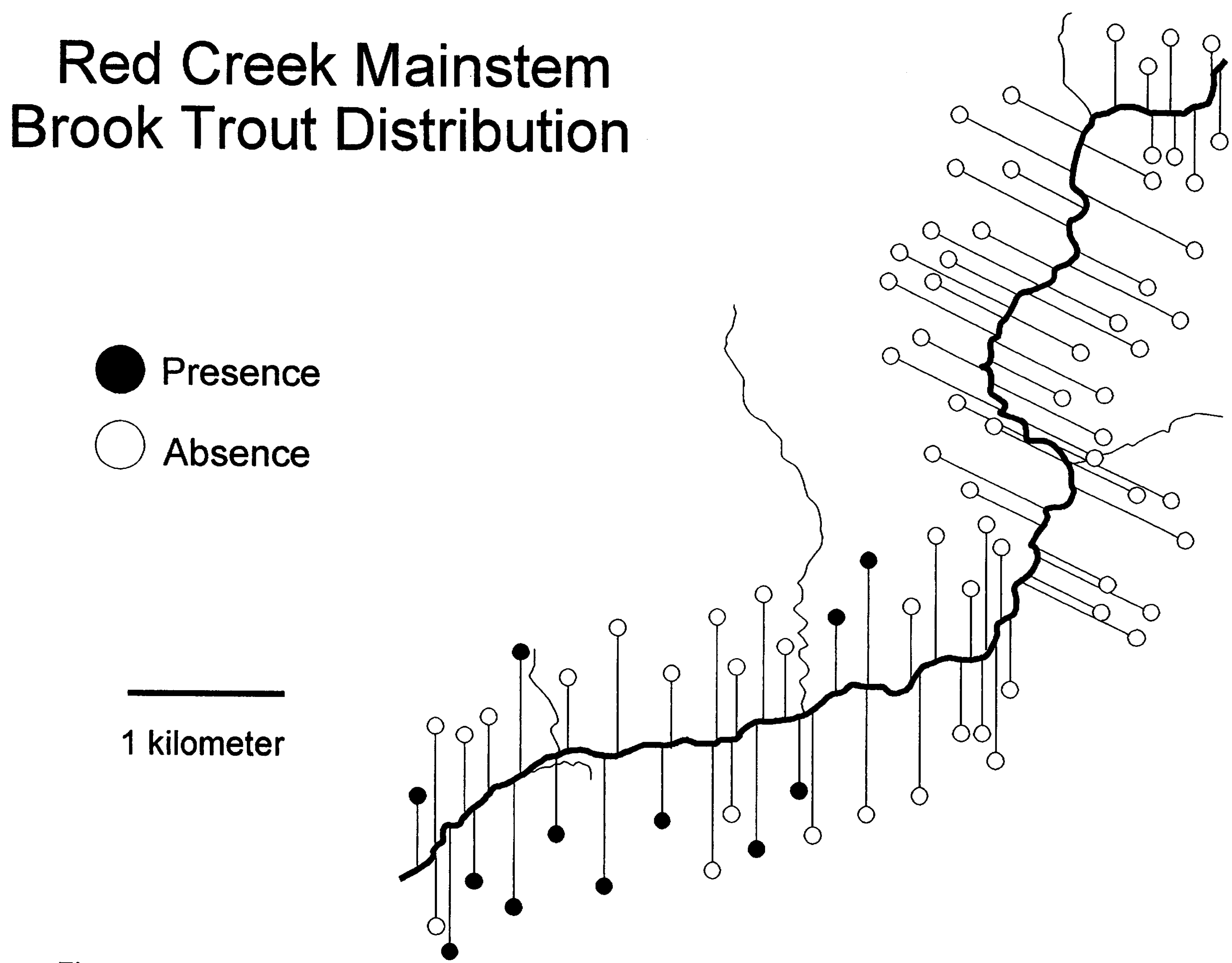

Figure 63. Distribution of brook trout in the Red Creek Watershed study area. Circles indicate sample sites. Solid circles represent sites where brook trout were present.

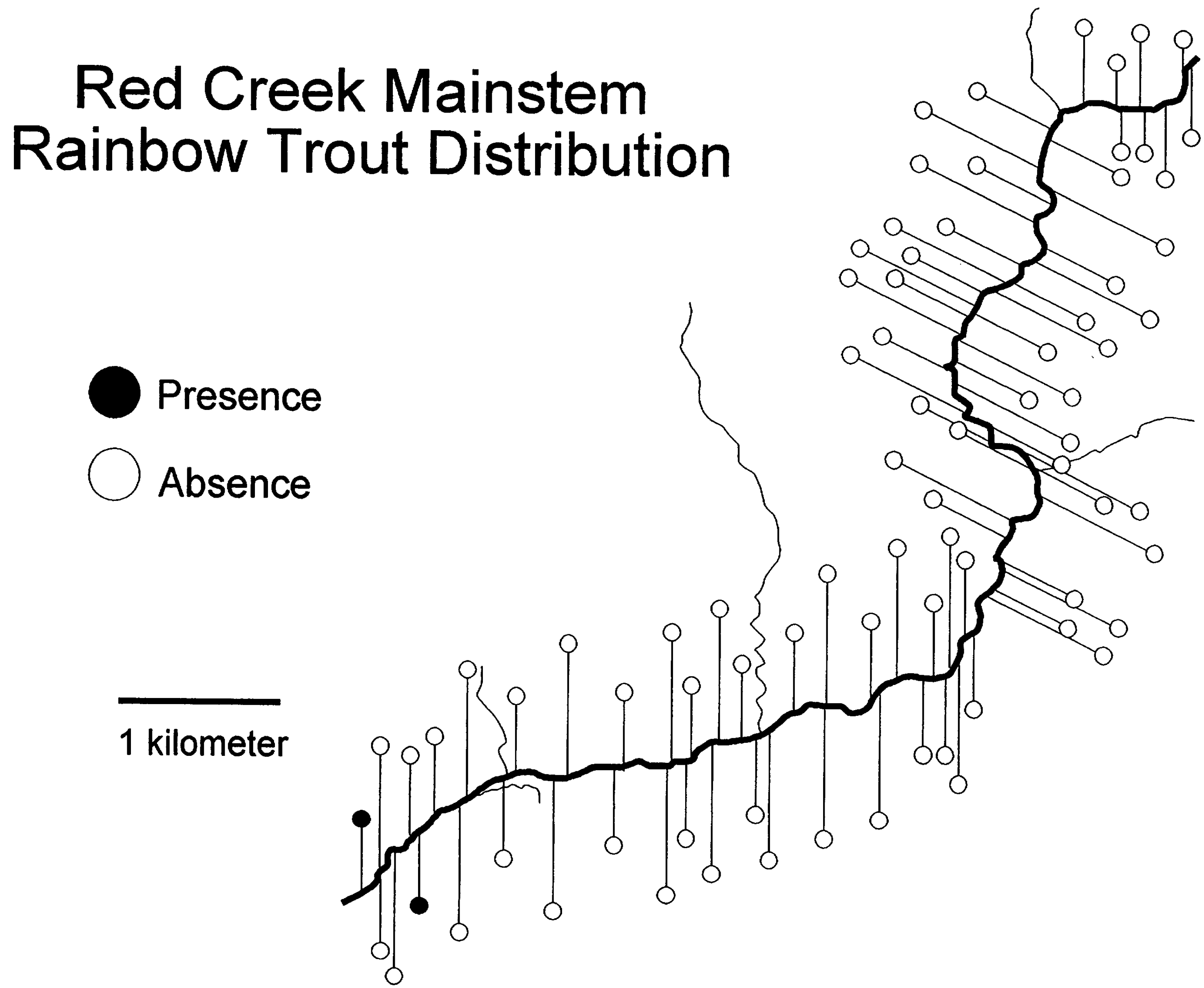

Figure 64. Distribution of rainbow trout in the Red Creek Watershed study area. Circles indicate sample sites. Solid circles represent sites where rainbow trout were present.

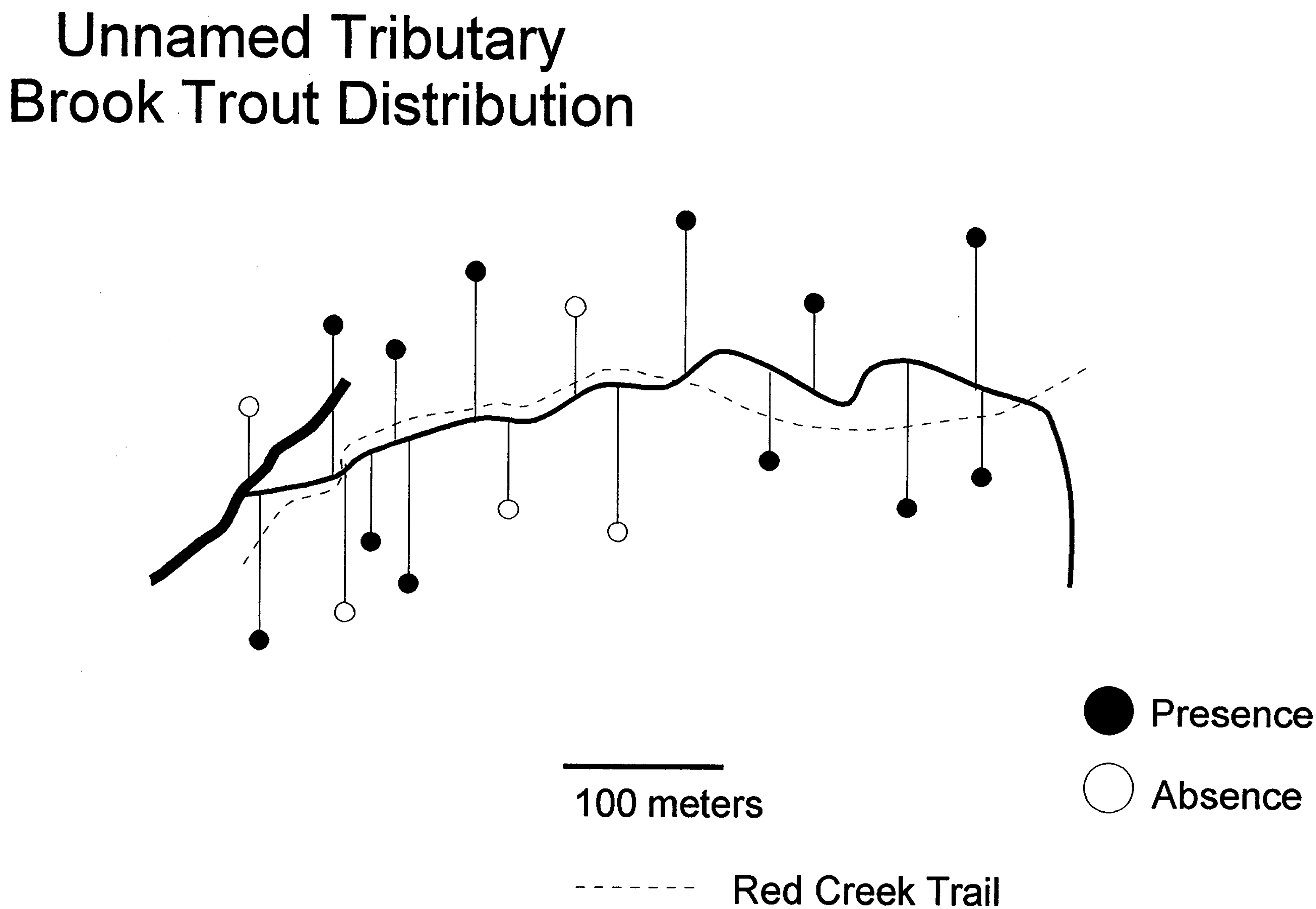

Figure 65. Distribution of brook trout (YOY) in the unnamed tributary study area. Circles indicate sample sites. Solid circles represent sites where brook trout (YOY) were present.

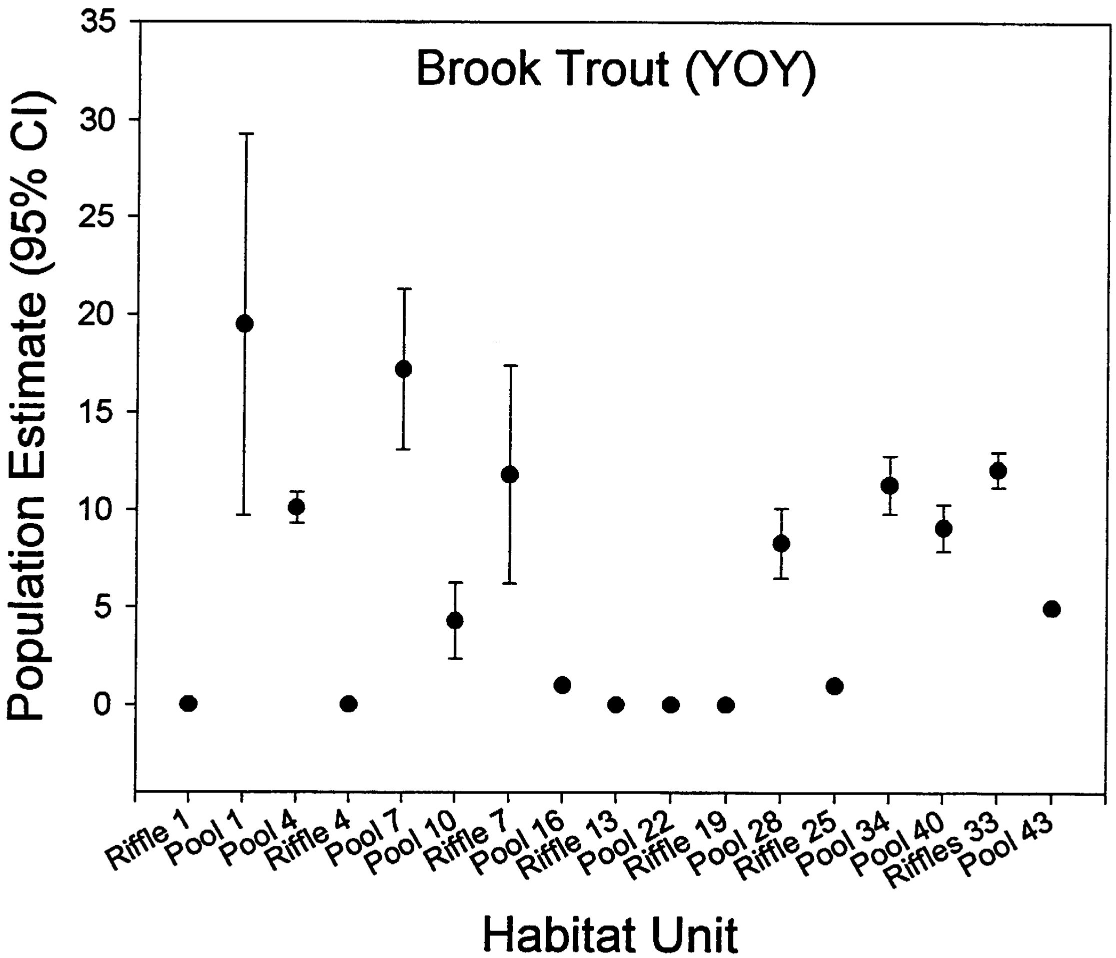

Figure 66. Scatter plot of population estimates for individual units electrofished in the unnamed tributary. Capped lines represent ranges of 95% confidence intervals.

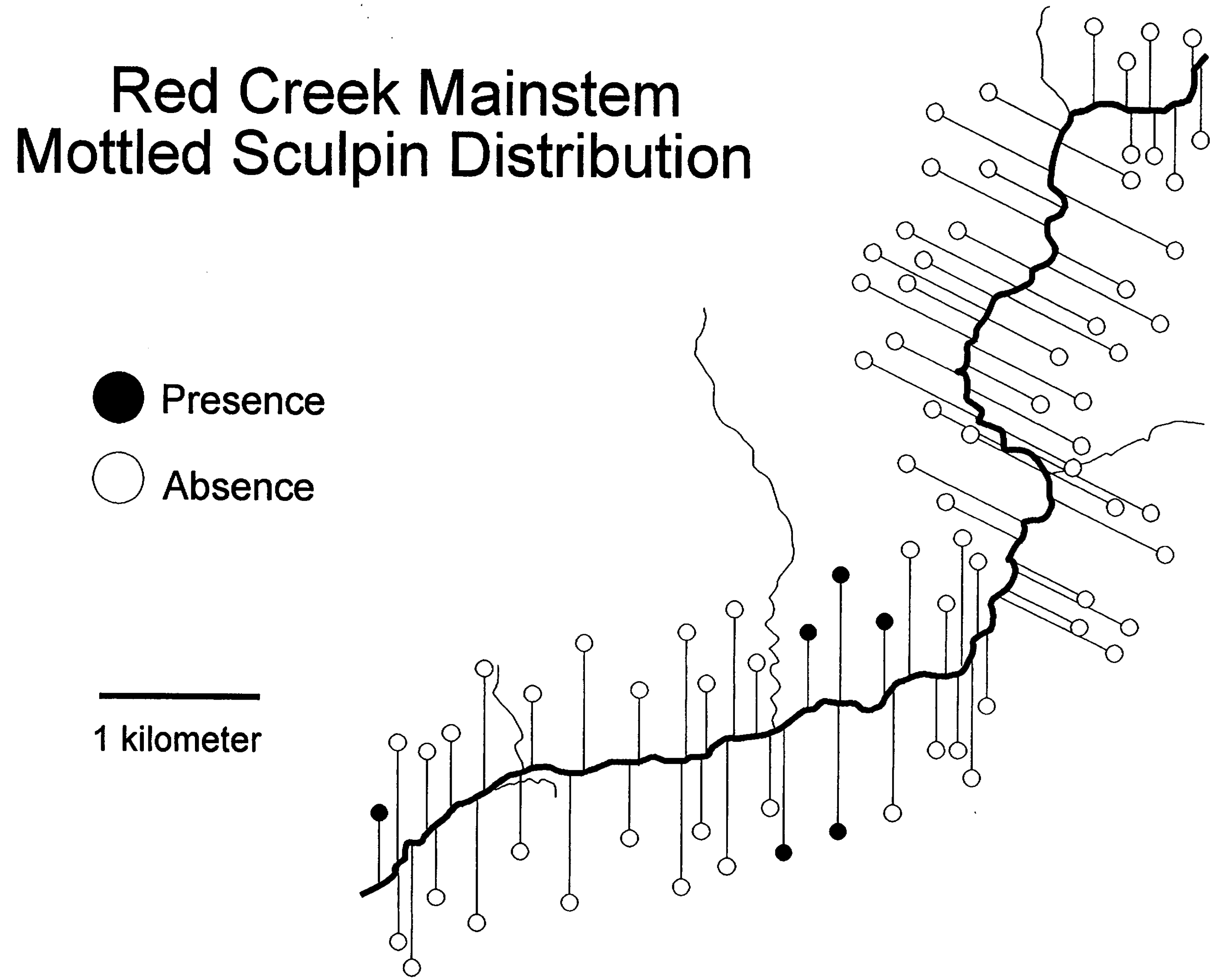

Figure 67 . Distribution of mottled sculpin in the Red Creek Watershed study area. Circles indicate sample sites. Solid circles represent sites where mottled sculpin were present.

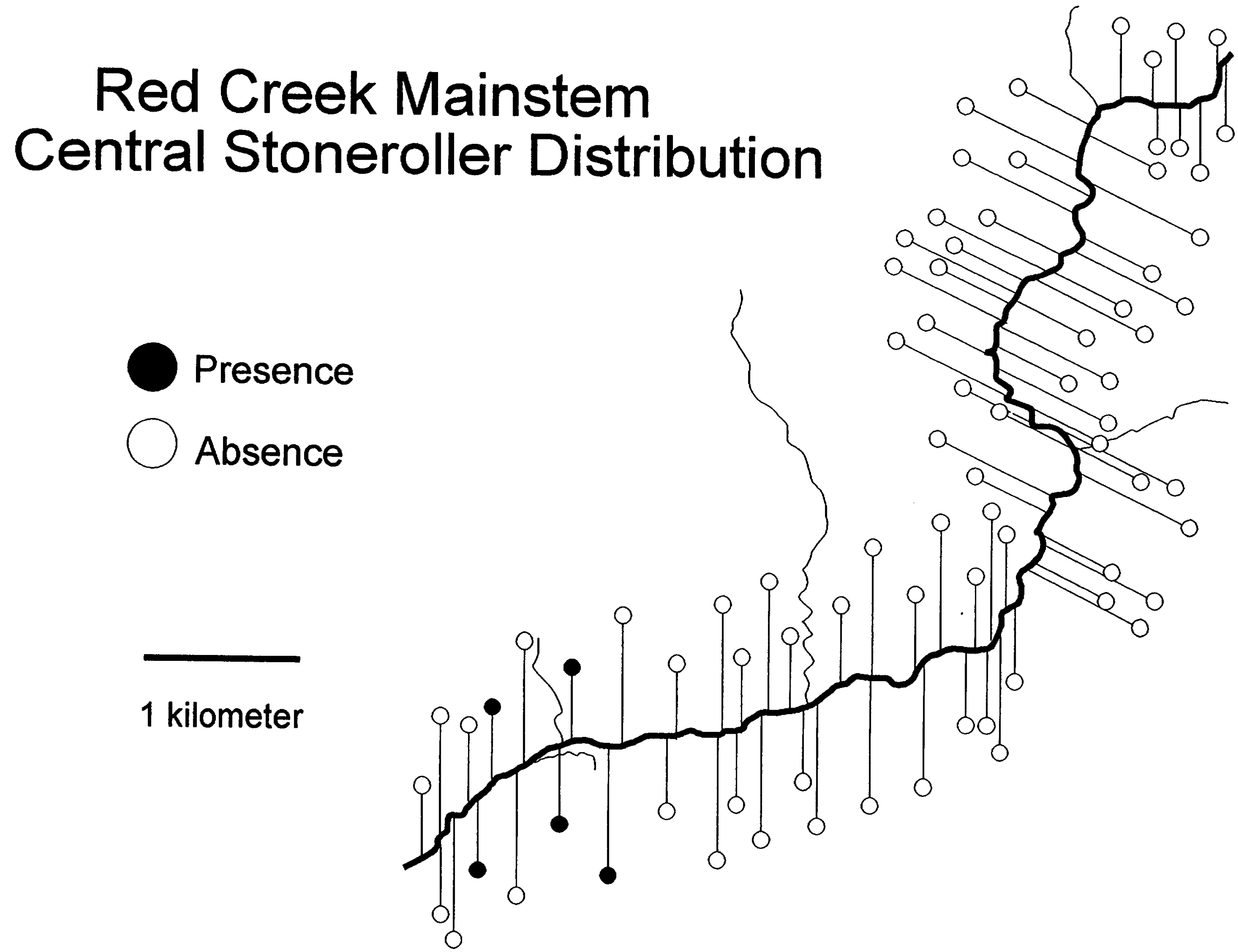

Figure 68. Distribution of central stoneroller in the Red Creek Watershed study area. Circles indicate sample sites. Solid circles represent sites where central stonerollers were present.

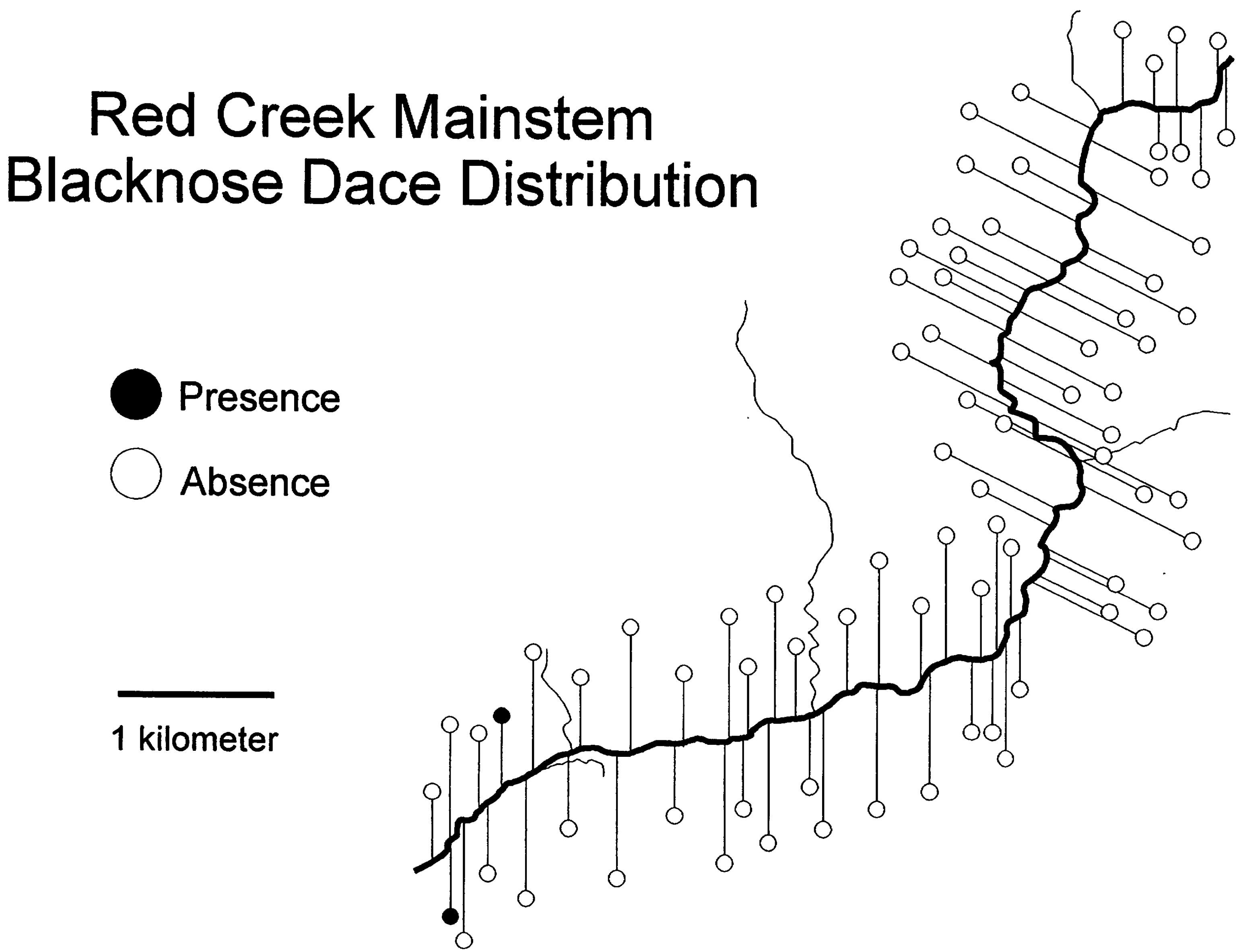

Figure 69. Distribution of blacknose dace in the Red Creek Watershed study area. Circles indicate sample sites. Solid circles represent sites where blacknose dace were present.

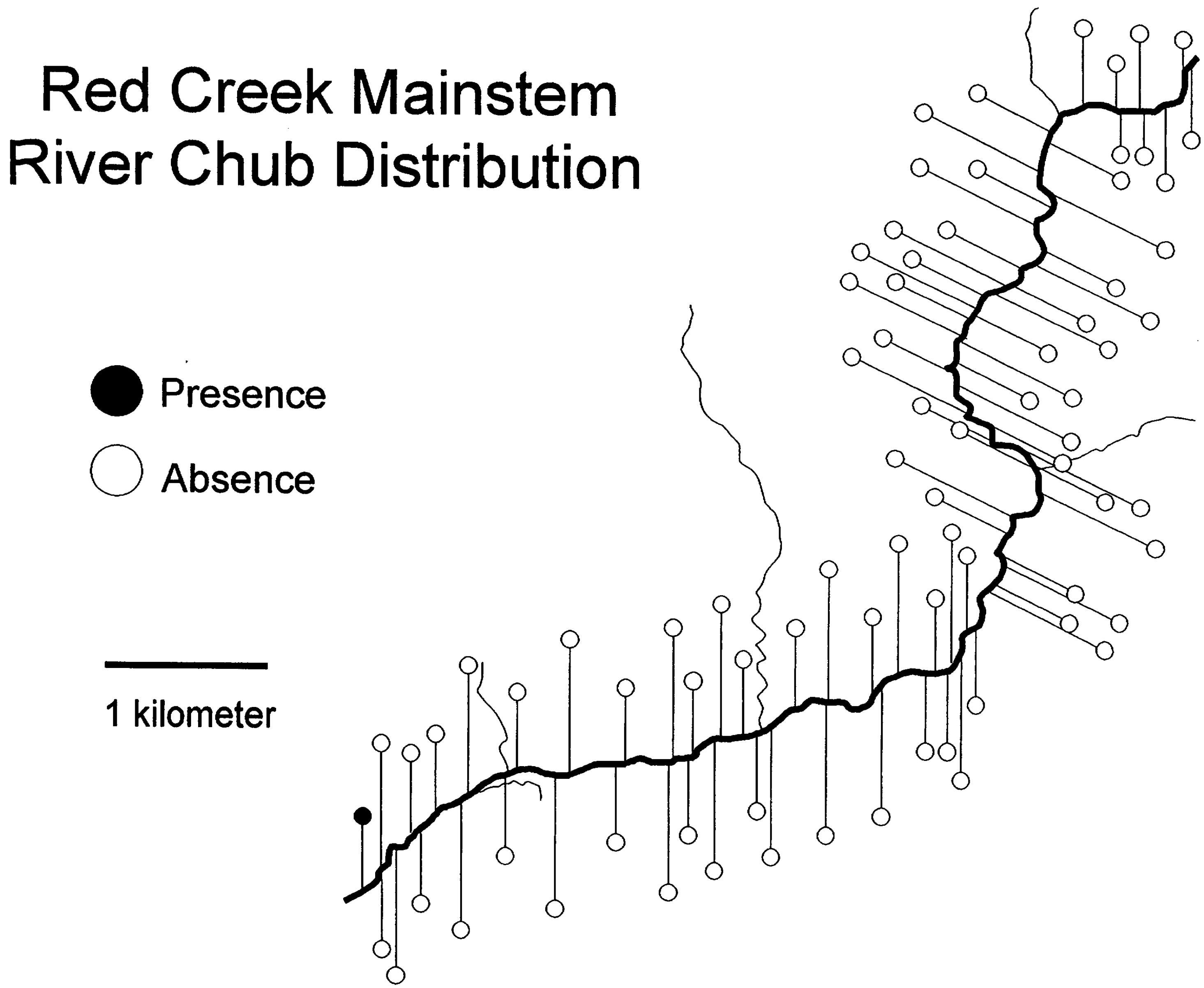

Figure 70. Distribution of river chub in the Red Creek Watershed study area. Circles indicate sample sites. Solid circle represents site where river chubs were present.

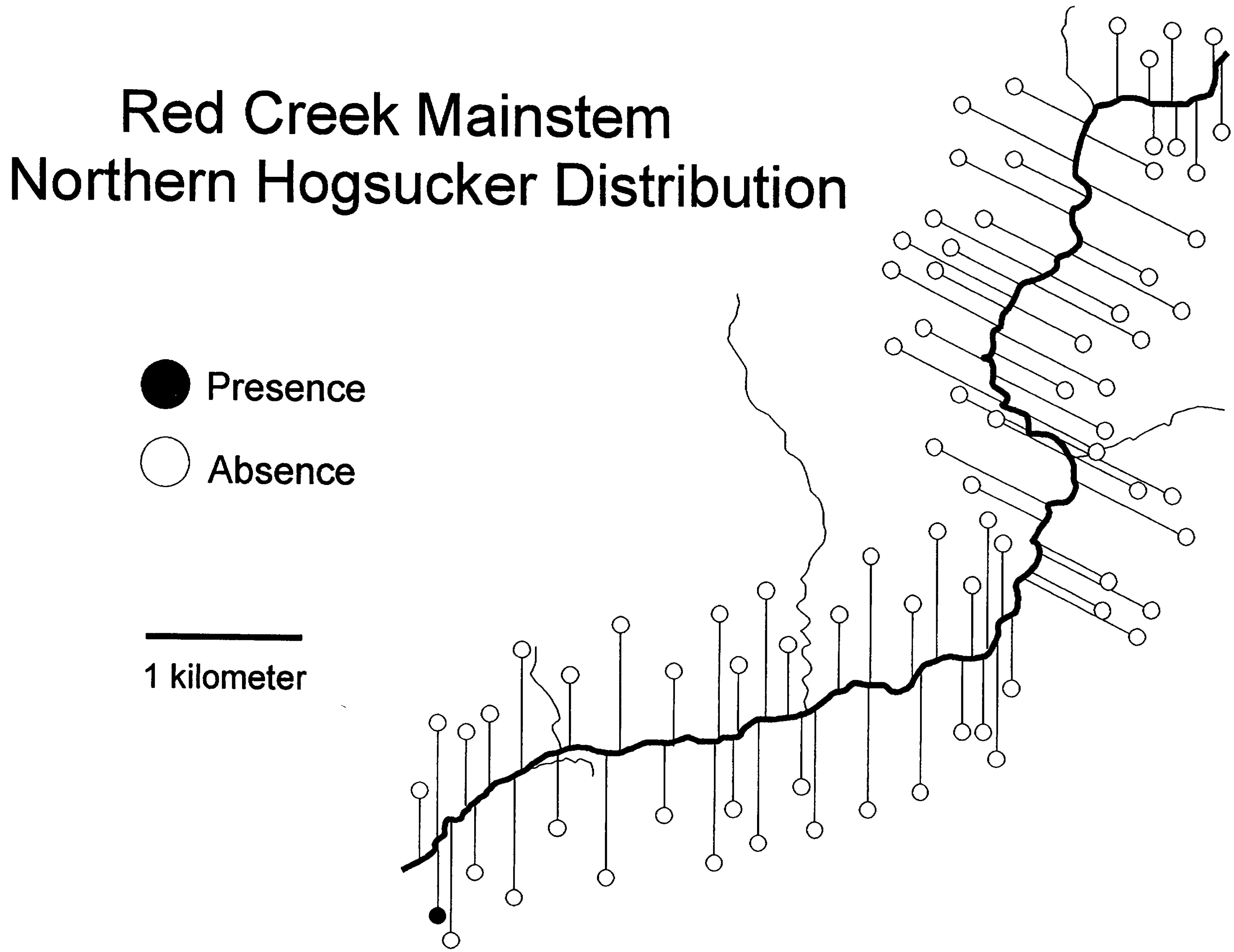

Figure 71. Distribution of northern hogsucker in the Red Creek Watershed study area. Circles indicate sample sites. Solid circle represents site where northern hogsuckers were present.

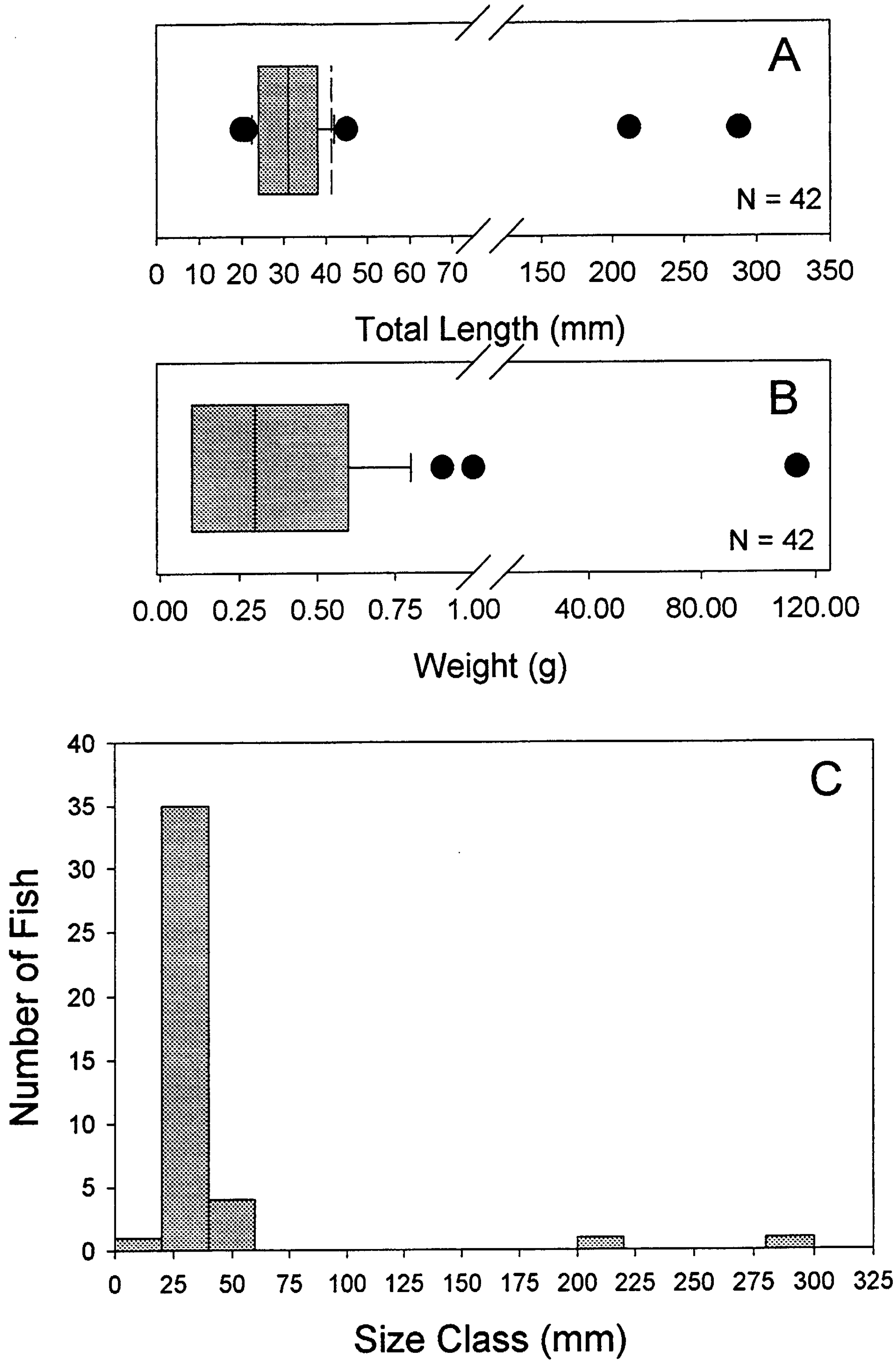

Figure 72. Summaries of fish data collected in the main branch of Red Creek for creek chub. A) Box plot of total length measurements; B) box plot of measured weights; C) length frequency histogram.

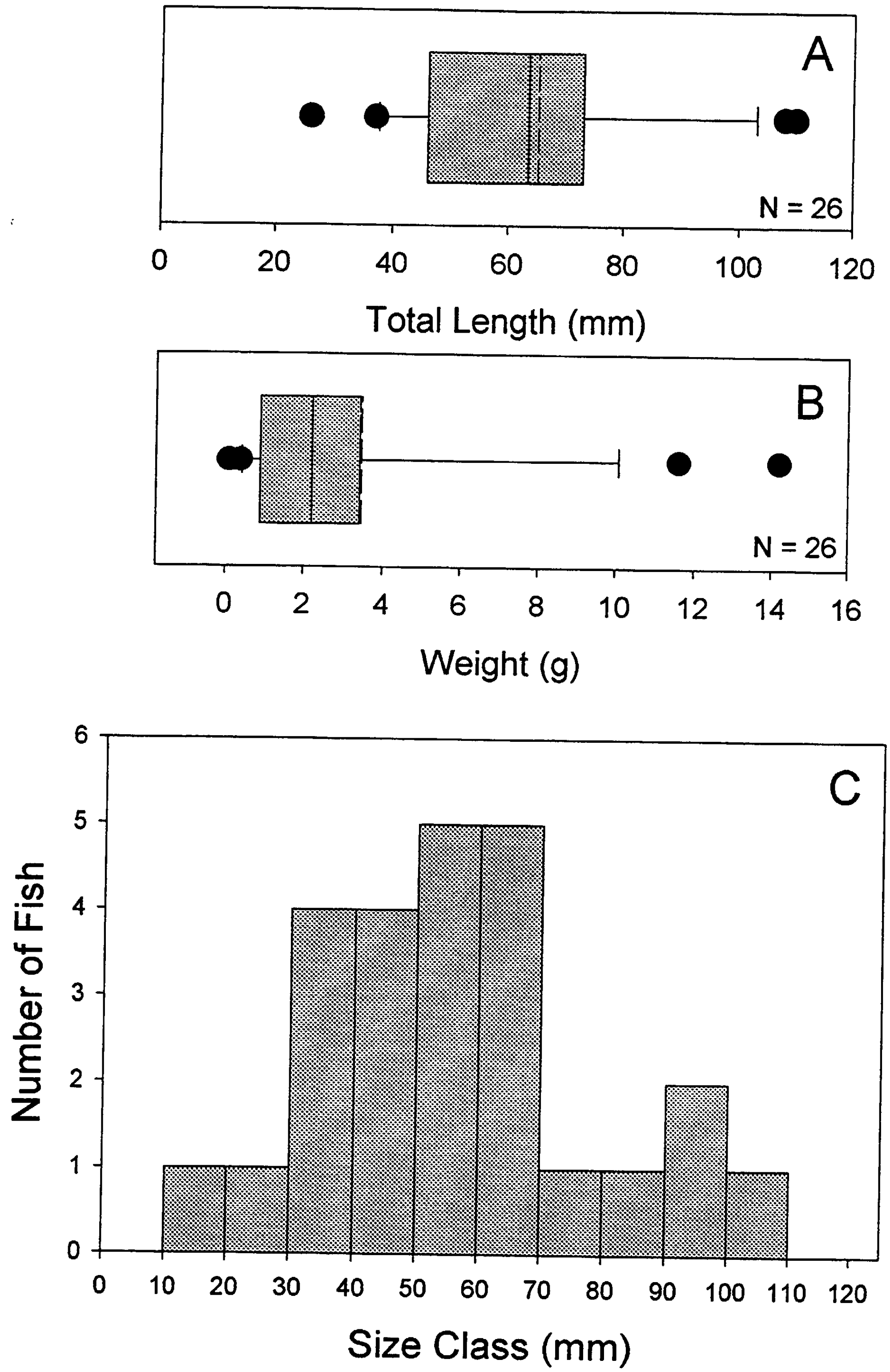

Figure 73. Summaries of fish data collected in the main branch of Red Creek for longnose dace. A) Box plot of total length measurements; B) box plot of measured weights; C) length frequency histogram.

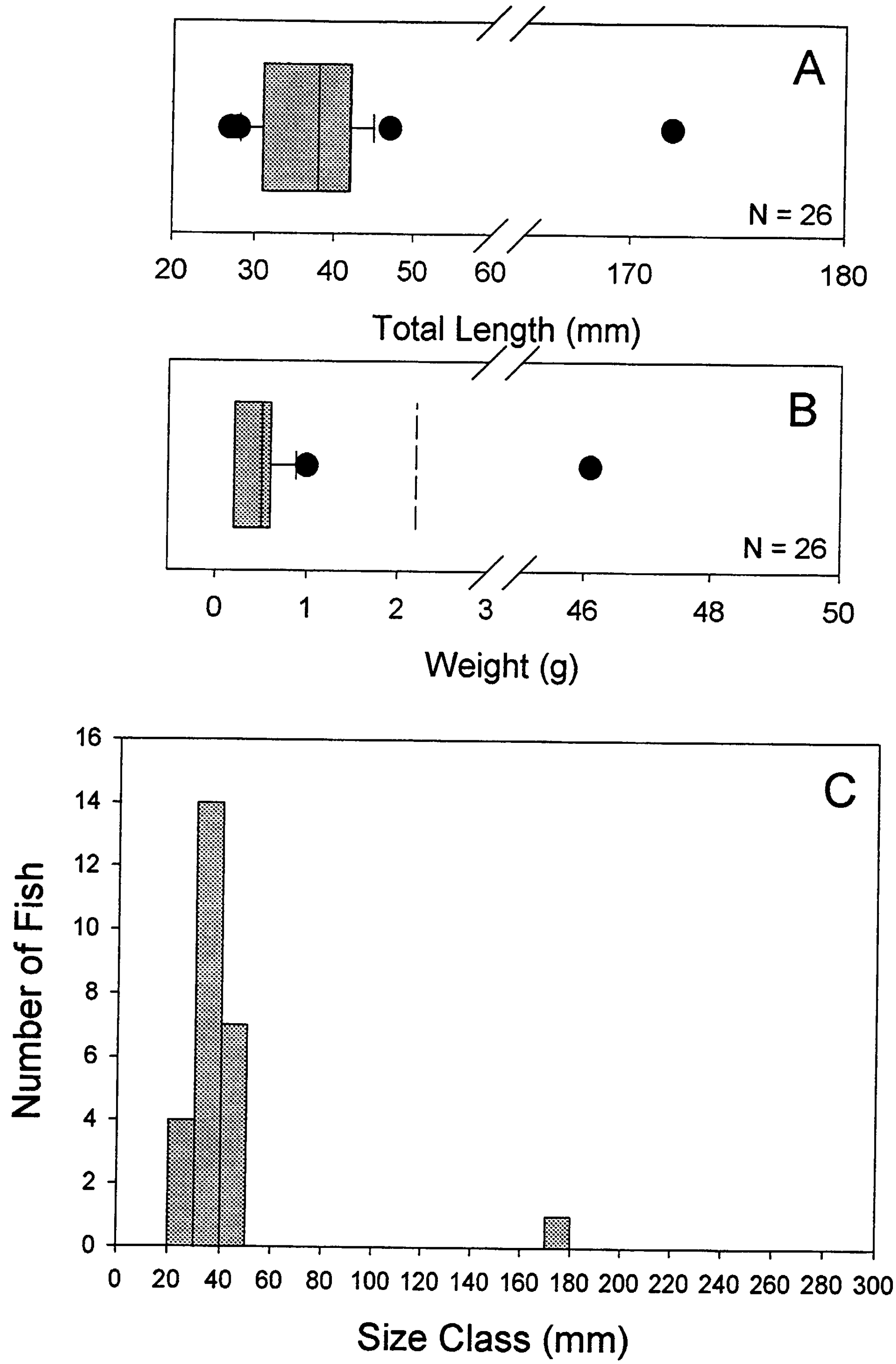

Figure 74. Summaries of fish data collected in the main branch of Red Creek for white sucker. A) Box plot of total length measurements; B) box plot of measured weights; C) length frequency histogram.

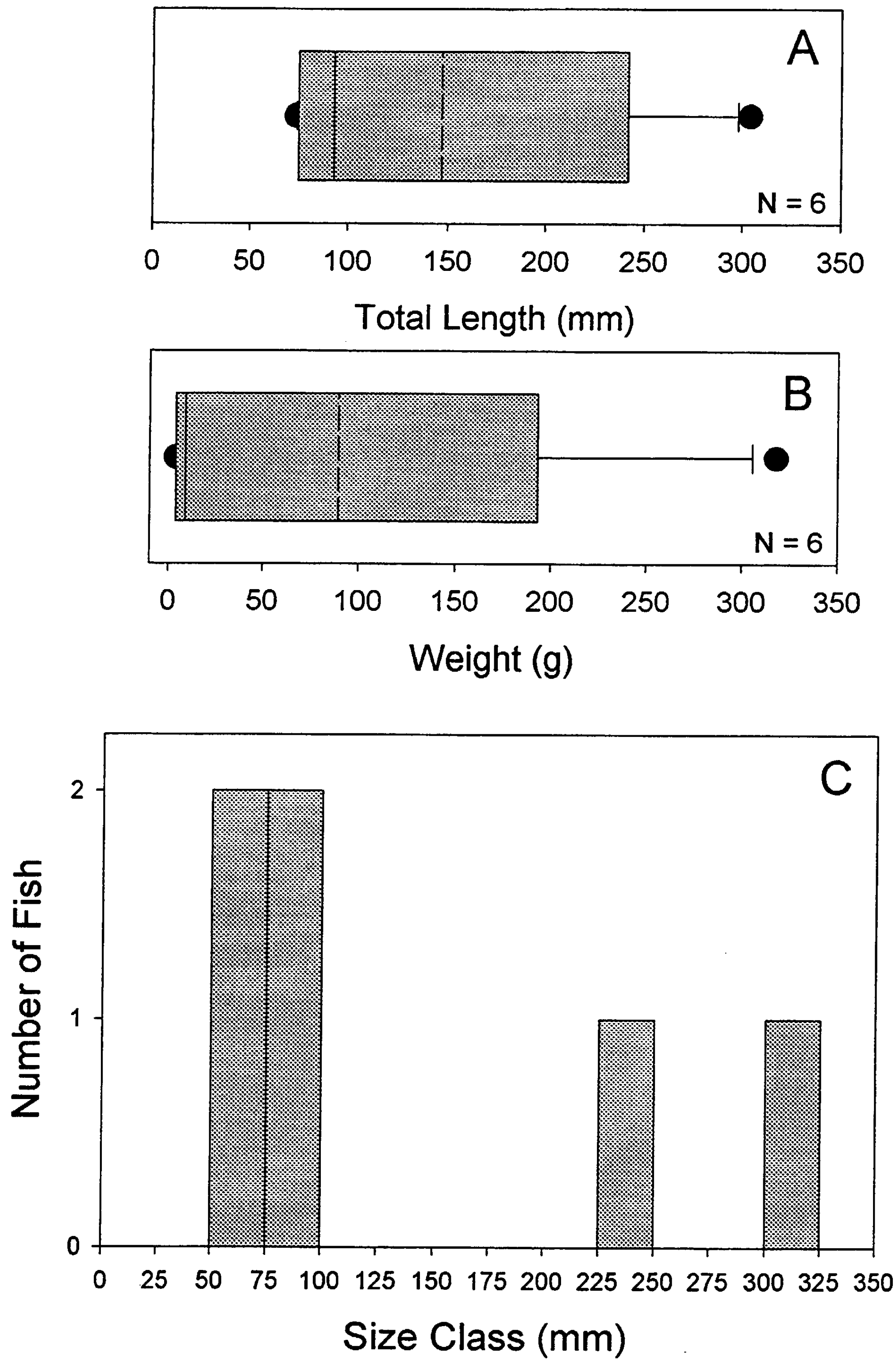

Figure 75. Summaries of fish data collected in the main branch of Red Creek for brook trout. A) Box plot of total length measurements; B) box plot of measured weights; C) length frequency histogram.

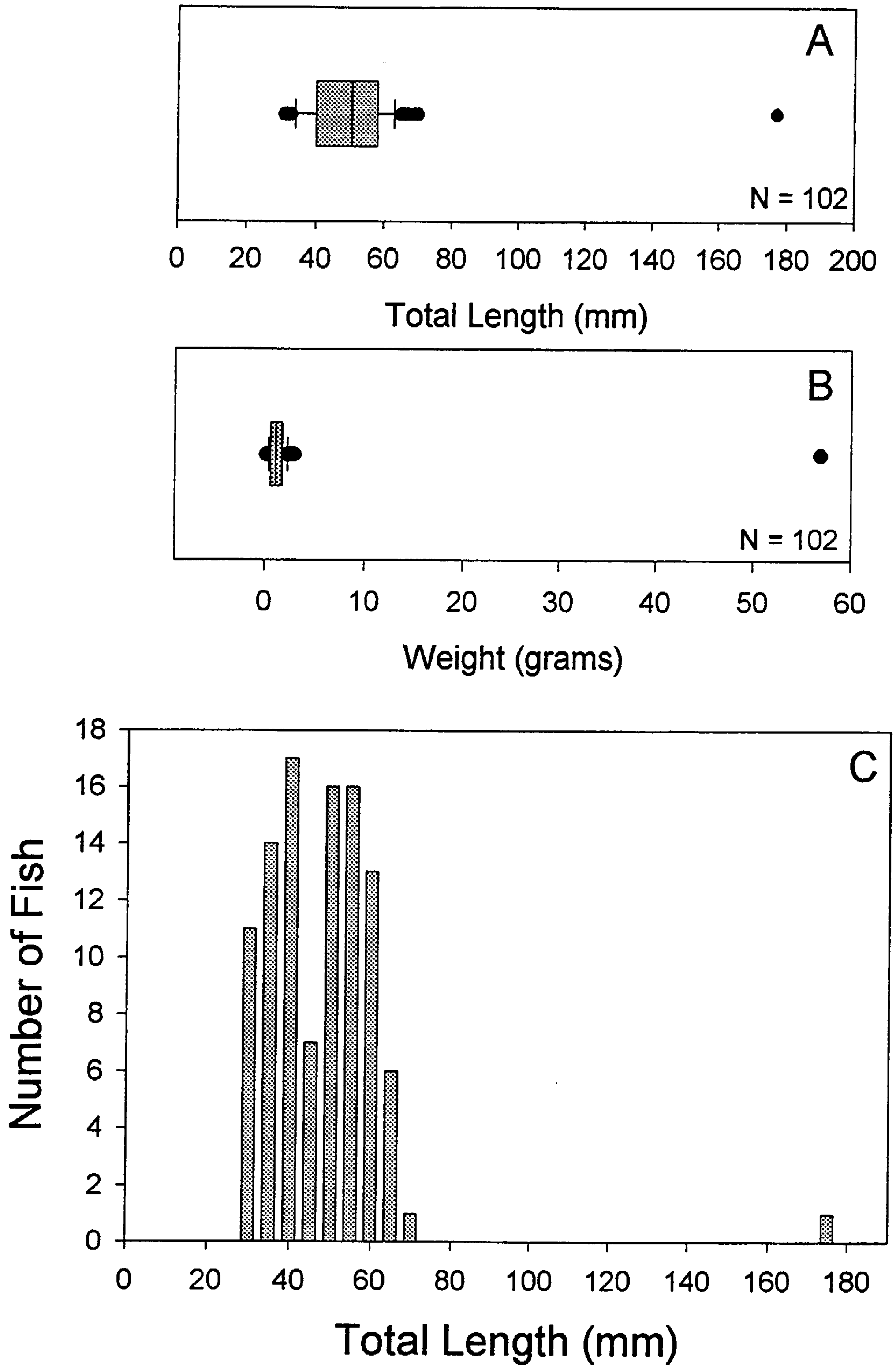

Figure 76. Summaries of brook trout data collected in the unnamed tributary. A) Box plot of total length measurements; B) box plot of measured weights; C) length frequency histogram.

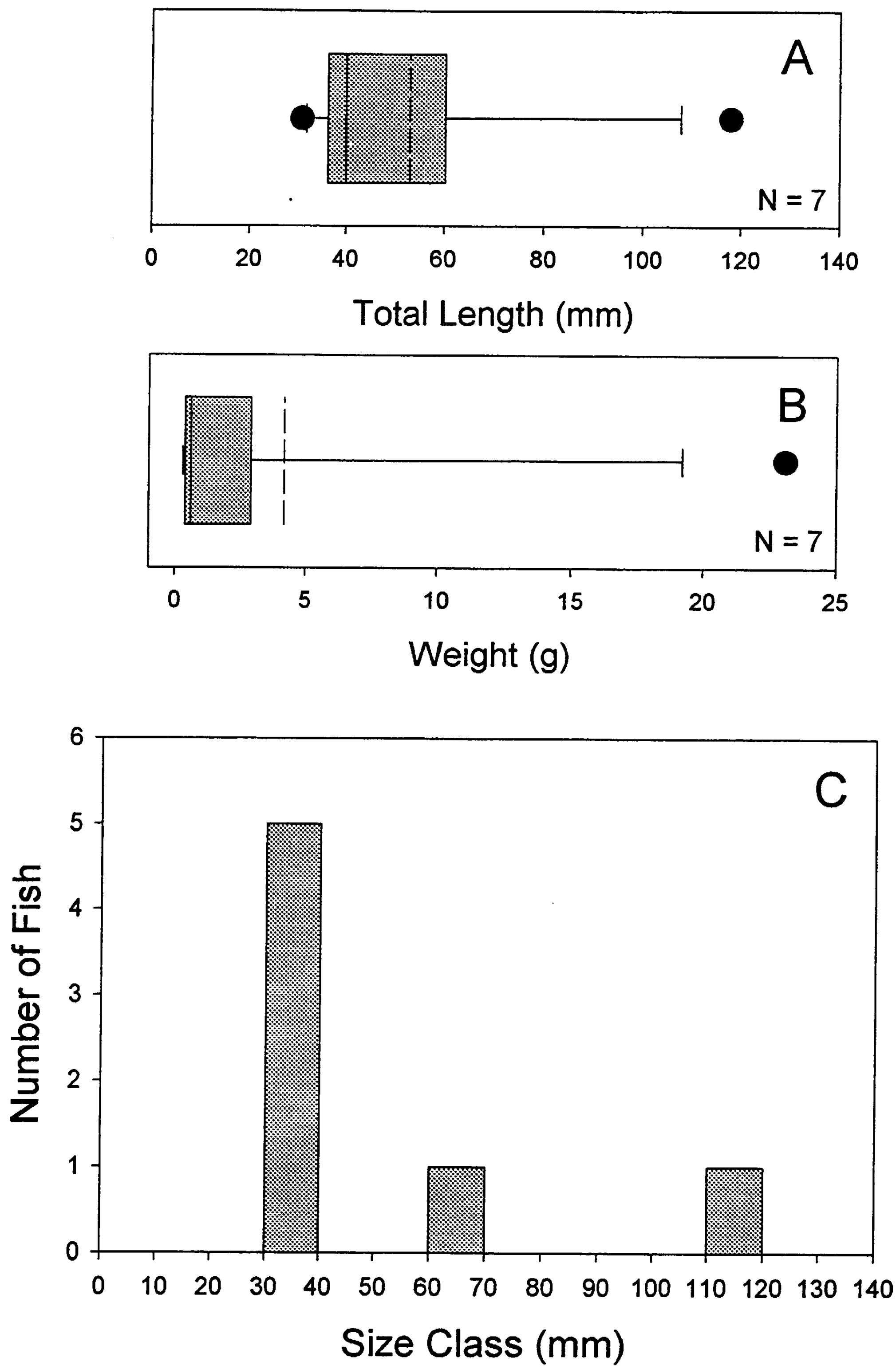

Figure 77. Summaries of fish data collected in the main branch of Red Creek for mottled sculpin. A) Box plot of total length measurements; B) box plot of measured weights; C) length frequency histogram.

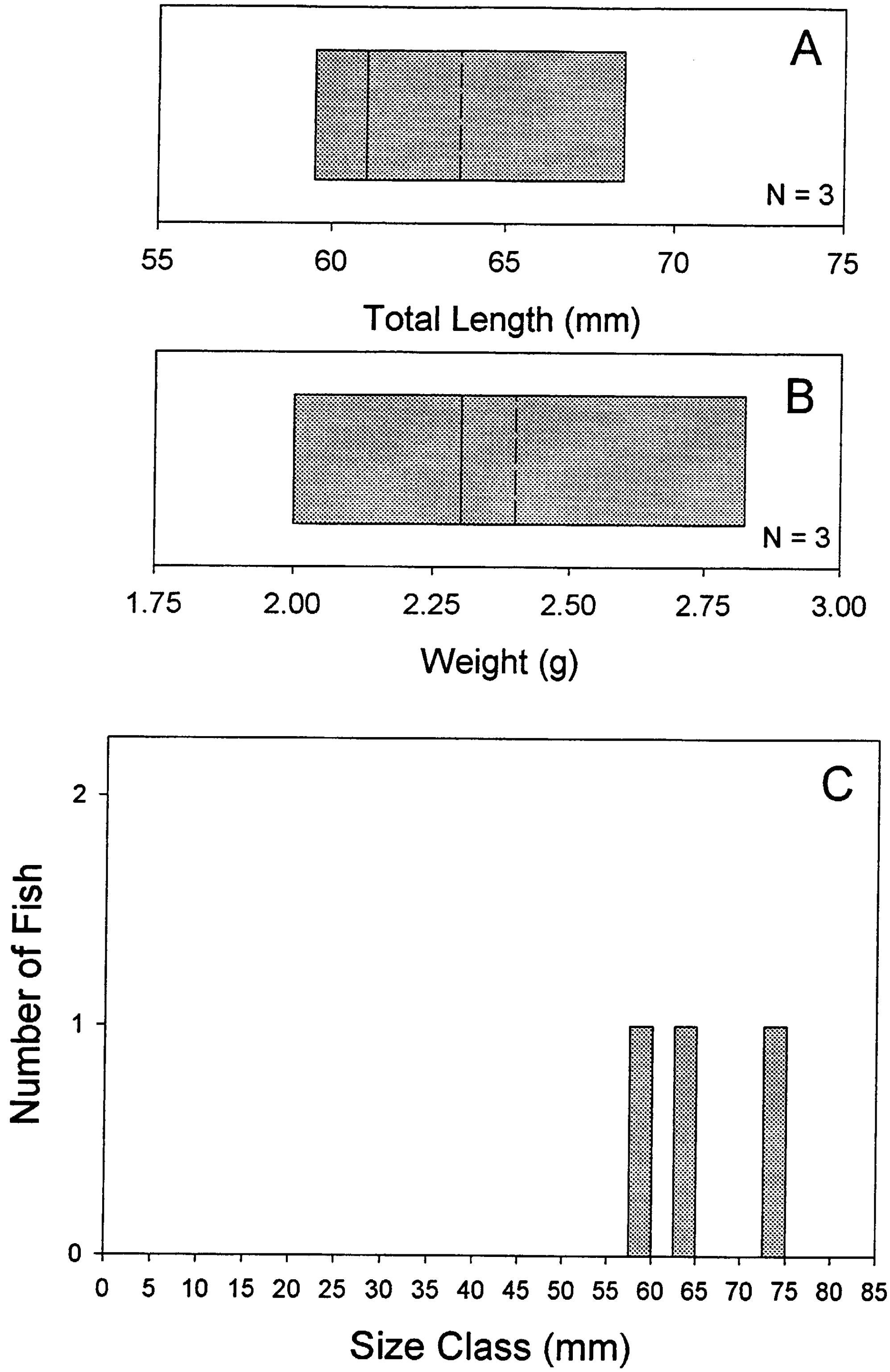

Figure 78. Summaries of fish data collected in the main branch of Red Creek for blacknose dace. A) Box plot of total length measurements; B) box plot of measured weights; C) length frequency histogram.

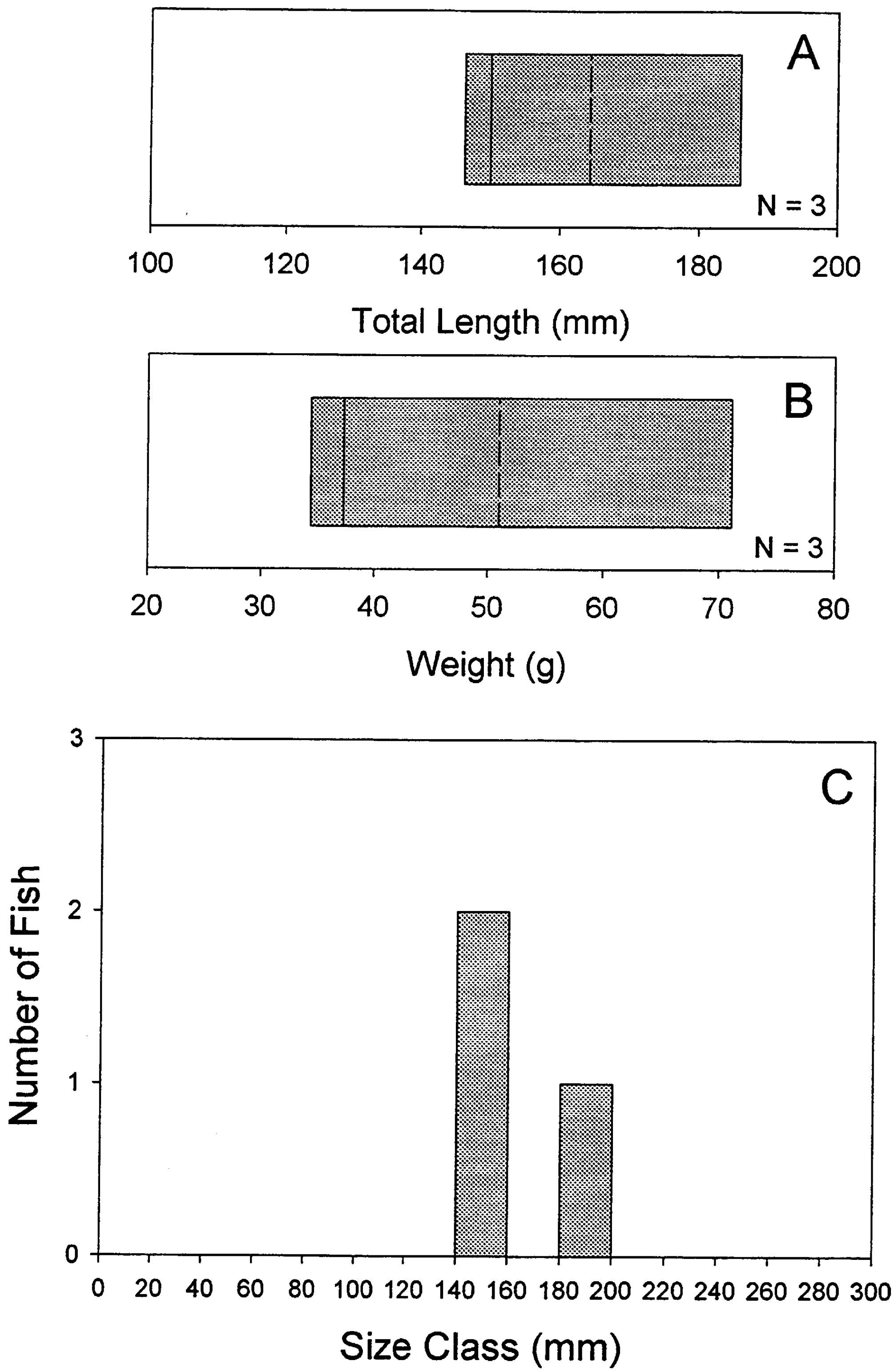

Figure 79. Summaries of fish data collected in the main branch of Red Creek for river chub. A) Box plot of total length measurements; B) box plot of measured weights; C) length frequency histogram.

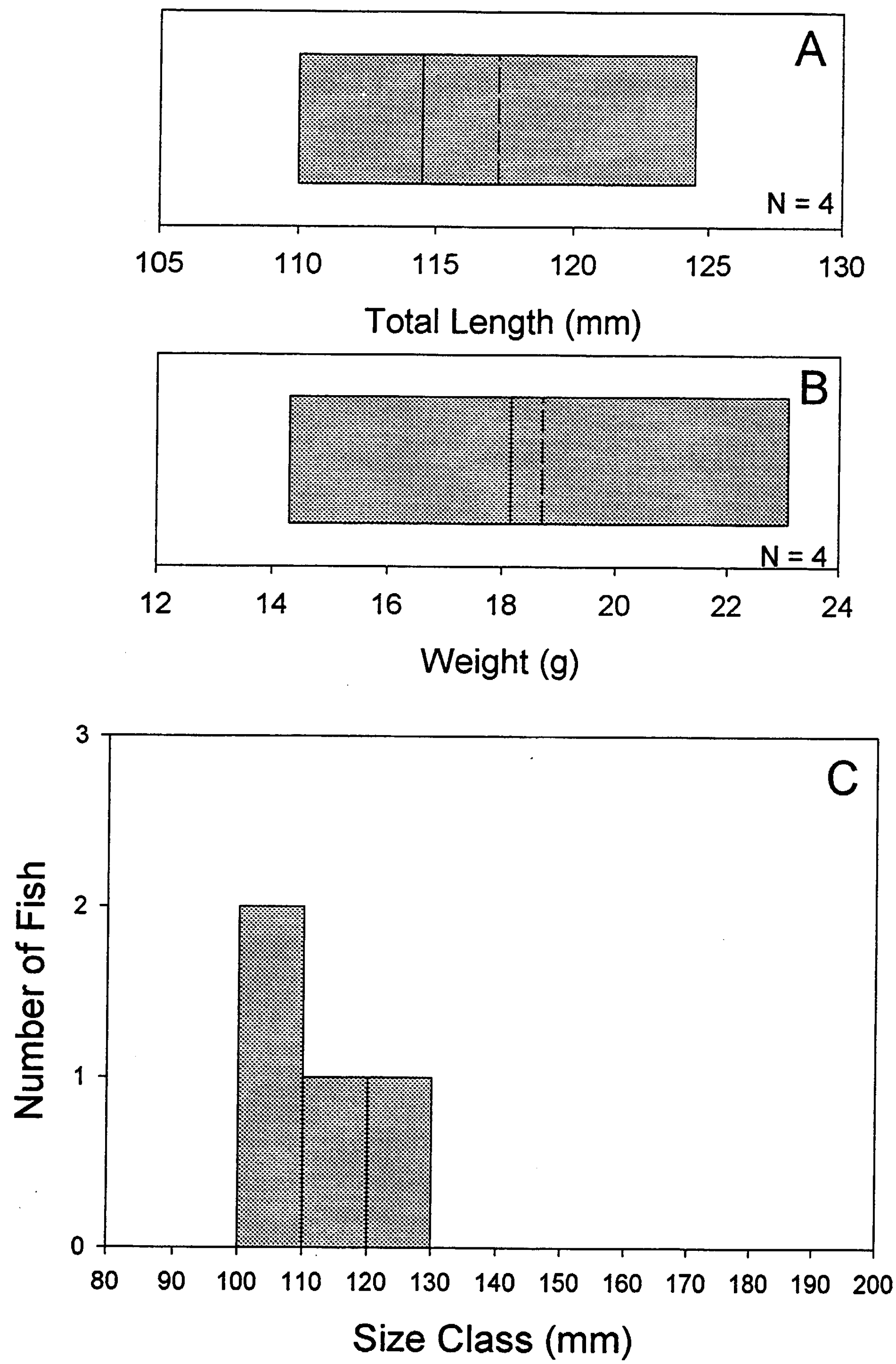

Figure 80. Summaries of fish data collected in the main branch of Red Creek for central stoneroller. A) Box plot of total length measurements; B) box plot of measured weights; C) length frequency histogram.

Appendix 1a. Substrate classification criteria.

SUBSTRATE CLASSES

1		organic debris
2		clay
3		silt
4	silt- 2mm	sand
5	2-10mm	small gravel
6	1-10cm	large gravel
7	11-30cm	cobble
8	30cm	boulder
9		bedrock

Appendix 1b. Large woody debris (LWD) classification criteria.

LWD SIZE CLASSES

Size 1) <15' in length and < 14" in diameter
Size 2) <15' in length and > 14" in diameter
Size 3) >15' in length and < 14" in diameter
Size 4) >15' in length and < 14" in diameter